ET Toolbox
Evapotranspiration Toolbox for the Middle Rio Grande
A Water Resources Decision Support Tool

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DRAFT


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2 Introduction

This documentation of the ET Toolbox is intended to provide information on the data sources, calculations, and formulations of the many output products. It also provides user guidance for navigating through these products located on the Internet.

This is a pdf document written to more easily accommodate reading and printing, using the Acrobet reader. The embedded figures are static, dated when aspects of this document were written. Dynamic real-time figures and tables are available by clicking on the W following the figure number. This will activate an Internet link via the users Web browser to the ET Toolbox Web site. Doing this during the winter months may produce limited ET and stream flow results.

This document will be updated as the ET Toolbox development occurs and related program changes take place.

3 Purpose of the ET Toolbox

The primary purpose of the ET Toolbox is to estimate high-resolution daily rainfall and water depletions (crop and riparian vegetation ET, and open water evaporation) within specified river reaches, and to provide these daily values for input into RiverWare, which is the river modeling and water accounting system used by the Upper Rio Grande Water Operations Model (URGWOM). The URGWOM is a multi-agency effort to develop a numerical computer surface water model that will cover the Rio Grande from its headwaters in Colorado to Fort Quitman, Texas. The primary purpose of this model is a daily water operations accounting tool that can be used for basin-wide water management and planning.

4 Overview of the ET Toolbox

The ET Toolbox builds on the Bureau of Reclamation (USBR) Agricultural WAter Resources Decision Support (AWARDS) system, adding Geographic Information System (GIS) land use to specify acreage, crop and riparian water use, and open water evaporation estimates for each Hydrologic Rainfall Analysis Project (HRAP) grid cell (resolution about 4 km x 4 km) along the Middle Rio Grande. The land use data are combined with weather station data-based ET estimates as calculated with a modified Penman equation to develop cell-by-cell water use estimates, adjusted for radar rainfall estimates, in acre-feet and cfs.

The Internet Web site address for the Et Toolbox is http://www.usbr.gov/pmts/rivers/awards/. The products include real-time access to weather station and stream gage data from the Middle Rio Grande Conservancy District (MRGCD), radar rainfall estimates, and links to United States Geological Survey (USGS) Stream gage data. The AWARDS/ET Toolbox system also receives daily weather data from the New Mexico Climate Center at New Mexico State University (NMSU) for calculating ET and Internet posting. Graphical plots of 5-day and 10-day running averages of daily ET are available to help detect water requirement trends. Other plots include total daily agricultural, riparian, open water, and urban ET.

Weather forecasting for the purposes of predicting ET for today and the next two days, and for substituting data for non-reporting weather stations, is accomplished by using the National Centers for Environmental Prediction (NCEP) Eta model weather forecast parameters.

Weather data used for calculating ET are the maximum and minimum temperatures, average relative humidity, average wind speed, and solar radiation for the previous 24-hour Mountain Standard Time (MST) day.

5 ET Toolbox Products - Navigating The Web Site

For operational and management purposes, the ET Toolbox provides products for both river reaches and MRGCD divisions (the MRGCD divisions are usually defined at the water diversion points). This versatility allows operation and management entities access to various consumptive use breakouts depending upon their needs.

5.1 Access to the ET Toolbox

Access to the ET Toolbox home page is via the Internet at (figure **??** . This page shows a map of the AWARDS and ET Toolbox project areas. Clicking on the Middle Rio Grande provides the New Mexico ET Products menu of available products, important links, archived precipitation products, and related links.

5.2 Colored Topography and No-Topography Options

The colored topography version of the inter-active ET Toolbox window (figure 1 W) shows the division windows outlined in black over the topography along the Middle Rio Grande. A colored elevation scale is provided.

The no-topography version of the inter-active ET Toolbox window (figure 2 W) shows the division windows outlined in white. Subsequent windows will maintain the selected version until the version is changed. Each window in both versions generally contains lands that receive water from a diversion dam usually located at the northern most edge of the window. Exceptions are when multiple windows are needed for clarity, or when diversions are not defined. The color scale at the bottom of these inter-active ET Toolbox windows, and subsequent windows, represents the 24-hour rainfall intensities that are mapped into each of the 4 km x 4 km HRAP grid cells.

The ET Toolbox products are generally available by clicking in the small square boxes found throughout various pop-up windows. For the AWARDS system ET charts, do not click in these boxes. For these areas, Refer to Agricultural Water Resources Decision Support (AWARDS) Products (section 6) later in this document.

Within each window there are small rectangular boxes containing pink lettering. These allow the user to move between windows, go to the AWARDS ET Toolbox home page, go to the New Mexico home page, go to an all window version, go to the parent window, turn on/off the topography, turn on/off the ET Toolbox vs AWARDS, etc. These options allow quicker movement around the Web site.

5.3 Division Windows

Clicking in the small white box attached to the left side of the windows allows access to the ET Toolbox products. An example ET Toolbox window for the MRGCD Angostura

Division (diversion) (figure 3 W) shows the green line river reach delineations between reaches 2, 3, and 4. The values printed on each cell are consumptive use in acre-feet for that cell.

5.4 Grid Cell Summary Tables

Clicking on a box in the lower-left corner of an HRAP grid cell, defined by the black dashed lines, (from the above example) will pop up a grid cell summary table. (grid cell summary example — figure 4 W). The vegetation classification source and weather station used for determining the consumptive use are noted. The table shows, for each day, the total consumptive use in cubic feet per second (cfs) with a breakdown for each vegetative type (agricultural, riparian, open water, and urban). The daily rain is the NEXRAD rainfall estimate. The daily URGWOM water use is the consumptive use minus the NEXRAD rain. Five and 10 day running averages of the water use are also provided. In the far right column is the total URGWOM water use to-date in acre-feet since January 1. The forecast method (FM) column next to the date signifies the method used to calculate the consumptive use for three forecast days, starting with today. An E indicates the 12-km grid Eta model weather forecast parameters were used, including Eta model forecast rainfall. In rare cases when the Eta model data were not available, an A indicates that an average of the last three days were used. In this case, the forecast rainfall will be zero. At the bottom of the cell summary is a tabulation of the acres of each vegetation type. The fallow and idle types are not included in the consumptive use calculations.

5.5 Grid Cell Detail Tables

Clicking within a grid cell will pop up a cell detail table showing each crop, riparian, open water, and urban acres for the cell. (grid cell detail example — figure 5 W).

The table includes the consumptive use for the last seven days and the next three forecast days. Today is considered the first of the forecast days. Near the bottom of the table are the daily NEXRAD rainfall estimates for the cell. The URGWOM water use is the consumptive use minus the NEXRAD rain. All quantities are in acre-feet. Those in parentheses are in cfs.

5.6 ET Toolbox, Reach and Division Summary Products Menu

ET Toolbox, Reach and MRGCD division summary products including tables and plots are available by clicking in the appropriate boxes from the ET Toolbox windows. (ET summary products menu example — figure 6 W). This example pops-up when clicking in the "River Reach 3 Summary" box from the MRGCD Angostura Division window. Note the various options that are available.

5.6.1 ET Toolbox, Reach and Division Summary Tables

The details of the reach and division table data are the same as the grid cell summary tables, except a number of weather stations and Eta model cells have been used for the calculations. Included in the reach summary tables are the daily flow differences, with five and 10 day running averages, as reported from real-time gaging station data. (reach summary example). Refer to Stream Flow Gages for gaging information (section 17

Following is a listing of the stream flow gages used to calculate the daily flow differences in the ET Toolbox and reaches 1, 3, 4, 5, and 6 summaries. This is not done in reach 2. The daily flows are an average of all the readings (usually at 30-minute intervals) acquired throughout the day.

ET Toolbox	Cross section at Cochiti Dam minus cross section at San Marcial
River Reach 1	Cross section at Cochiti Dam minus cross section at San Felipe
River Reach 3	Cross section at San Felipe minus cross section at Central Avenue
River Reach 4	Cross section at Central Avenue minus cross section at Bernardo
River Reach 5	Cross section at Bernardo minus cross section at San Acacia
River Reach 6	Cross section at San Acacia minus cross section at San Marcial

There are two plots available from the ET Toolbox Products menu:

5.6.2 Plot of Total Consumptive Use, Agricultural, Riparian, Open Water, and Urban, with Rain

The first plot contains a chart (in cfs) of the total daily consumptive use, affected by rain, and traces for each vegetative type, unaffected by rain. A bar chart of the NEXRAD rainfall estimate (in cfs) is also included. These data are plotted for the past 18 days, plus the three forecast days, starting with today. A break in a trace indicates there were no data available for that period of time. (figure 7 W).

5.6.3 Plot of Total Consumptive Use with Five and Ten-Day Running Averages, with Stream Gage

The second plot contains a chart (in cfs) of the total daily consumptive use, affected by rain, and traces of the five and 10 day running averages of the total. Also included are similar traces of the actual streamflow data from real-time gaging stations. Note that the streamflow traces are not included in the MRGCD division plots. (figure 8 W).

5.6.4 Daily ET Rate Table

Another system of tables is available for each of the reaches. These contain the daily ET rates for each crop within each vegetative type for the reach, with a notation of the acres and source of the classification. Clicking on a crop pops up the table containing detailed information about the parameters used to calculate ET. These include the acres, planting and harvest dates (start and stop dates), reference ET, crop coefficient, crop ET, NEXRAD rain, and URGWOM water use, for each day from the planting date through yesterday. These are the data that are accumulated for the reach and division table. (daily ET rates example — figure 9 W).

5.7 Situation Analysis Matrix

The Situation Analysis Matrix is available from the main New Mexico ET Products menu. There are two matrixes that show the past, current (today), and predicted (future) status of the stream flow, rainfall, and consumptive use. The area of consideration is from the Otowi gage to the San Marcial gage. The period for the past is eight days, and the predicted is three days as determined by the Eta forecast period. The rainfall is the summation of NEXRAD over all the HRAP grid cells for the area. The daily consumptive use is the total of agricultural, riparian, open water, and urban for the area. All units arte in cfs, except the current (today) rainfall is in inches.

Currently there are no data available for predicting stream flow at the Otowi and San Marcial gages. When these become available the plots will be completed.

The only difference between the two matrixes is the current (today) rainfall. The With Present Division Rain (figure 18 W) matrix contains rainfall breakouts for the Cochiti (COC), Albuquerque (ABQ), Belen (BEL), and Socorro (SOC) divisions of the MRGCD. The With Present Hourly Rain (figure 19 W) matrix contains rainfall for each hour since midnight.

Archived matrixes are also available, where SAdivrain is division rain, and SAavgrain is the hourly rain. Each is followed by yymmda01.png.

6 AWARDS Products

There are three AWARDS products available by clicking directly into a black or white (depending whether the user selected the colored topography or no-topography option) outlined window from the inter-active ET Toolbox window.

6.1 NEXRAD Rainfall Estimates

The first AWARDS product is the NEXRAD rainfall estimates. Refer to NEXRAD Precipitation Estimates (section 9) for more information.

6.2 Weather Station Data

The second product is the weather station data available by clicking on the orange, green, or blue plus signs (+) shown in many of the windows. Refer to Automated Weather Station Data (section 7) for more information.

6.3 ET Charts

The third product is available by clicking into the HRAP cells to pop-up a generalized ET chart showing the ET for all crops/riparian vegetation that may be in the area. No acreages or rainfall values are used in these calculations. The heading at the top of each chart shows the name of the weather station data that were used to calculate the daily crop water use for the past four days. ET for three forecast days, starting with today, are provided, as well as the sum of ET to-date and the sum for the last seven and 14 days. Each weather station is assigned to an array of HRAP cells, therefore the ET portion of the charts may be identical for nearby cells. The start (plant) and stop (harvest) dates are also given. An example date value of 101 represents January 1. The value 1020 represents October 20. (figure 10 W)

Near the bottom of each chart is a posting of the NEXRAD rainfall estimates for the HRAP cell. Since the NEXRAD data are collected via FTP from the West Gulf River Forecast Center (WGRFC) on an hourly bases, the number of actual hours received are noted, generally 24. The total rain and calculated effective rain are provided. Refer to Effective Rainfall Estimates (section 10) for more information.

The column headed QPF is the Quantitative Precipitation Estimate that is collected via FTP from the WGRFC eight times per day. The NEXRAD monthly total rain (since the beginning of the current year) and the HRAP cell number are also provided.

7 Automated Weather Station Data

Weather data from five sources are used, or presented, within the AWARDS and ET Toolbox products. They are:
Middle Rio Grande Conservancy District (MRGCD), New Mexico Climate Center (NMCC), University of New Mexico Sevilleta Long-Term Ecological Research (LTER) Network, Colorado State University Agricultural and Meteorological Network (COAGMET), and Automated Surface Observing System (ASOS).

Example of automated weather station used in the MRGCD network.

7.1 Middle Rio Grande Conservancy District

MRGCD weather station network presently consists of 8 sites; additional weather stations are expected to be added in the near future. Hourly data are automatically received from this network via File Transfer Protocol (FTP) at 12 minutes past each hour. Clicking on WX Hourlys from the The inter-active ET Toolbox window (figure 1 W) pops-up an image showing the location of the MRGCD weather station network. (figure 12 W) Clicking on the plus (+) signs pops-up the hourly weather data for the last 24-hours. (figure 13 W) These hourly data are converted to the Standard Hydrometeorological Exchange Format (SHEF) shortly after they are received, and provided, via FTP, to the West Gulf River Forecast Center. Refer to NEXRAD Precipitation Estimates (section 9) for more information.

The 24-hr summaries that are used in estimating ET are received around 1:12 AM MST from the MRGCD. These sites are shown in orange on the inter-active ET Toolbox window, and sub-windows, on the Internet. If the 24-hr precipitation accumulations are available they are shown on the image at the locations; otherwise the site IDs are shown. Weather stations are represented on many of the windows with plus (+) signs that locate the stations by latitude and longitude. Clicking on a + sign pops-up a table containing the station name, elevation, and location. Data for the past seven days is shown in the upper part of the table consisting of max and min temperatures, average wind speed, relative humidity, rain, and solar radiation as measured by the station's sensors. The gage monthly rain totals are also tabulated. The bottom part of the table contains all of the data for each day since January 1st. Included in this listing is the calculated Penman Reference ET. Refer to Penman Reference ET Calculation (section 11) for more information. If station data are unavailable for a day, alternate weather data from the Eta weather forecast model from the previous day are used. Refer to Weather Forecasting (section 8) for more information. An alternate data key provides information on data that may have been substituted. Example: In the Alternate Weather Data column eta1TS means the Eta model 1st forecast day temperatures and solar radiation were used. In cases when the Eta model data are also unavailable, data from a nearby weather station are used, with the 1st 4 character station ID posted under Alternate Weather Data. If that weather station is also unavailable, a second alternate station is used.

The operational MRGCD weather stations are (from north to south):

Site Name	ID
Pena Blanca	PBLN
Angostura	ANGN
Candelaria Farms	CFMN
Jarales	JRLN
Boys Ranch	BOYN
San Acacia	IHFN
Luis Lopez	LLZN
North Bosque	BANN

7.2 New Mexico Climate Center

In addition to the MRGCD network, previous day's meteorological data for ET estimation are also obtained via FTP from the New Mexico Climate Center (NMCC) at New Mexico State University. The 24-hr data are received at 4:30 AM and again at 10:30 AM MST to get missing data. The 24-hr precipitation accumulations from these stations (or site IDs if data are missing) are shown in green on the inter-active ET Toolbox window, and sub-windows, on the Internet. (figure 1 W) The same rules for alternate weather data apply as described above for MRGCD data.

The NMCC network weather stations are (from north to south):

Site Name	ID	Ownership
Alcalde Agricultural Science Center	ALCA	NMCC
Los Lunas Agricultural Science Center	LOSL	NMCC
South Bosque	SBOS	MRGCD
Elephant Butte	ELFB	BoR
Derry Station	DERR	NMCC
Jornada Range	JORN	LTER
NMSU Golf Course	NMSU	NMCC
Las Cruces National Weather Service	NWS	NWS
Horticultural Experimental Station	HORT	NMCC
Leyendecker Plant Science Research Center	LASC	NMCC
La Union Station	LAUN	NMCC

7.3 Long-Term Ecological Research

University of New Mexico Long-Term Ecological Research (LTER) Network data are received via FTP at 6:15 AM and again at 10:15 AM MST. The 24-hr precipitation accumulations from these stations (or site IDs if data are missing) are shown in blue on the inter-active ET Toolbox window, and sub-windows, on the Internet. (figure 1 W) Data from the LETR meteorological stations are not used for the calculation of ET, because the sites generally lie outside the irrigated crop and riparian zones. Available hourly data are also collected and stored at the above times but are not used or displayed in the AWARDS and ET Toolbox products.

LETR sites (from north to south) are:

Site Name	ID
Bronco Well	45
Red Tank	43
Cerro Montoso Well	42
Deep Well	40
LTER Field Station	01
Rio Salado	44
South Gate Well	41
Blue Springs	48
Five Points	49

7.4 Colorado State University Agricultural and Meteorological Network

Colorado State University Agricultural and Meteorological Network (COAGMET) data are received via FTP at 6:18 AM and again at 10:18 AM MST. The 24-hour precipitation accumulations from these stations (or site IDs if data are missing) are shown in blue on the Upper Rio Grande window accessed from the home page: (W). Data from the COAGMET meteorological stations are not used for the calculation of ET at this time. Expansion of the ET Toolbox into the Upper Rio Grande may occur in the future.

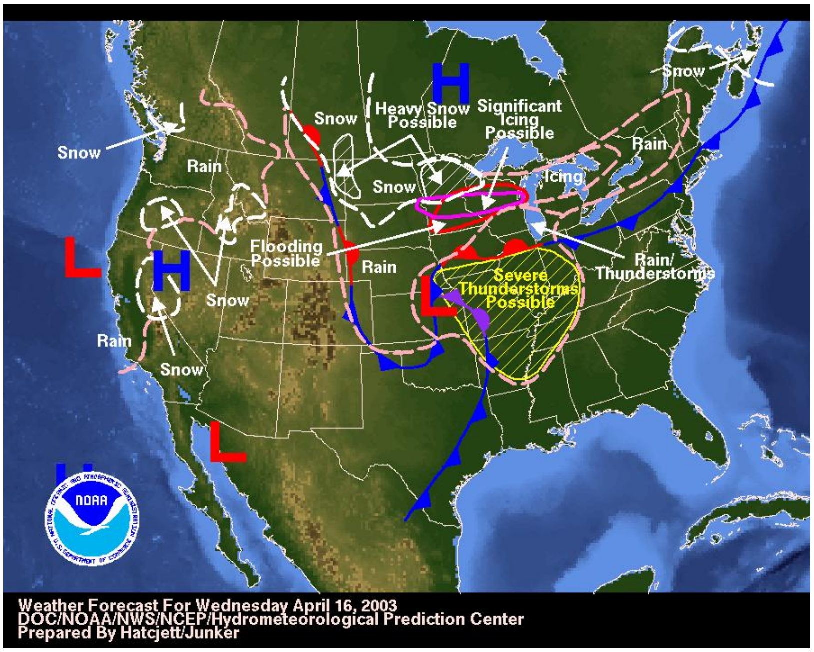
COAGMET sites (from north to south) are:

Site Name	ID
Center, CO	CSU San Luis Valley Res Ctr
Blanca, CO	8 mi SW of Blanca
San Luis, CO	

7.5 Automated Surface Observing System

The AWARDS - ET Toolbox system also collects precipitation data from the federal Automated Surface Observing System (ASOS). The 24-hr precipitation accumulations from these stations (or site IDs if data are missing) are shown in pink on the inter-active ET Toolbox window on the Internet. (figure 1 W) Data from the ASOS sites are not used for the calculation of ET, because these weather stations do not have solar radiation sensors.

8 Weather Forecasting



Example Weather Forecast Map.

The National Centers for Environmental Prediction (NCEP) Eta model weather forecast parameters at 12-km grid resolution are used for the ET Toolbox's ET forecasts for today and the next two days. The ET Toolbox uses the Eta model 0600 UTC (0000 MDT) run's 3-hr forecasts for temperature, relative humidity, and wind speed, plus the forecast cumulative solar radiation and precipitation for 0600-0600 UTC. From the 3-hr forecast values, the ET Toolbox selects the maximum and minimum temperatures, and calculates the average relative humidity and wind speed. The Eta model-based 24-hr ET forecasts from the previous day are used in the ET Toolbox when weather station data are unavailable. The Eta data are collected at 10:00 PM, midnight, and 2:00 AM via FTP. The three attempts are made to assure that missing data are received. These data are acquired for all of the United States west of the Mississippi River, and then clipped for the areas of interest.

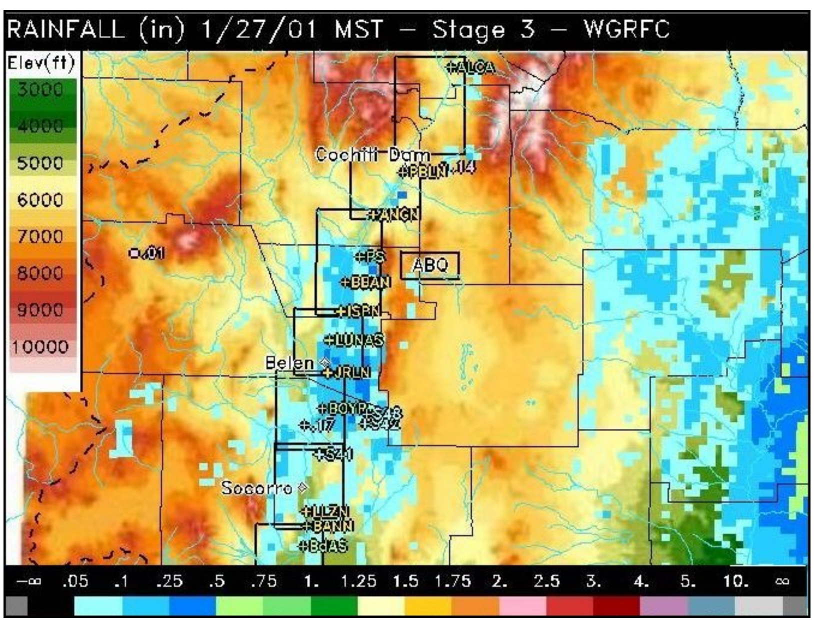
An example of of the 12-km NCEP grid (Eta cell) for the Middle Rio Grande is shown in figure 14. The x,y numbering system (in red) is used to identify the 12-km grid cells. Each weather station is cross referenced to an Eta cell. In this more detailed example (figure 15) of the Belen North window with topography background, the Los Lunas (LOSL) weather station is in Eta cell 258,163. However, this is a special case example where Los Lunas is re-assigned to Eta cell 259,163 which has a lower more representative elevation and agricultural/riparian presence. All weather and ET forecasting for the Los

Lunas station, and forecast from the previous day if the station data are unavailable for today, are provided by the data from Eta cell 259,163. The Jarales (JRLN) station remains in Eta cell 258,161.

9 NEXRAD Precipitation Estimates

Radar-based precipitation estimates are used in the ET Toolbox to offset ET demands. Digital data files containing an hourly radar precipitation product called Stage 3 are obtained via FTP from the National Weather Service's (NWS) West Gulf River Forecast Center West Gulf River Forecast Center (WGRFC). Hourly data from the MRGCD's weather stations are provided to the WGRFC in real-time for their use in developing the Stage 3 product. Radar data obtained from multiple NEXRAD weather surveillance radars that cover the WGRFC's area of responsibility (including the Rio Grande) are quality controlled, adjusted using surface gage measurements and merged into the NWS Hydrologic Rainfall Analysis Project (HRAP) approximate 4 km x 4 km grid. The ET Toolbox accumulates and uses the hourly Stage 3 files into a 24-hr file covering the midnight-midnight MST period. The 24-hr rainfall (average depth) for each HRAP grid cell located over the agricultural, riparian, open water, and urban acreage along the Rio Grande is used in the water use calculations. These precipitation estimates are represented by a color spectrum placed at the bottom of each inter-active ET Toolbox window.

In the AWARDS sub-window, (Belen North example — figure 11 W) the non-zero precipitation estimate is posted within each HRAP cell. These values are not placed into the ET Toolbox windows since they contain ET estimates.



Example of radar-based precipitation estimates over the MRGCD area.

10 Effective Rainfall Estimates

By definition, effective rainfall is that portion of rainfall that contributes to meeting the ET requirement of a crop (ASAE, 1983). Rainfall that neither leaves as surface runoff nor contributes to excess surface drainage may be effective precipitation in the context of irrigation management. An estimation of effective rainfall is made and presented in the ET charts (part of the AWARDS process). Soil types, terrain slope, and soil moisture are not current components of the AWARDS system; therefore a simplified method apparently developed by the Bureau of Reclamation is implemented. The published method bases effective precipitation on increments of monthly rainfall. The AWARDS system uses this monthly process to reduce daily total rainfall into daily effective precipitation (not a scientifically proven assumption). The relationships used are:

Table 1: Effective Rain As A Percent Of Total Rain

Total Rain (in)	Effective Rain (%)
$r < .5$	100
$0.5 \leq r \leq 1.0$	95
$1.0 < r \leq 2.0$	90
$2.0 < r \leq 2.0$	85
$3.0 < r \leq 2.0$	75
$4.0 < r \leq 2.0$	55
$5.0 < r \leq 2.0$	35
$6.0 < r$	5

The effective precipitation process explained above is not currently used within the ET Toolbox (only the Awards system charts). When future research provides a better method, possibly by using soil types, terrain slope, and remotely sensed soil moisture, then the above will be replaced and used within the ET Toolbox product to reduce daily water use requirements.

11 Penman Reference ET Calculation

The Penman Reference ET Equation written in Fortran (figure 16) and most of the crop and riparian coefficients that are used in the ET Toolbox were provided by Dr. Salim Bawazir at the New Mexico State University (NMSU) on March 16, 2000. This is the Penman calculation with evapotranspiration referenced to grass (Eto in inches), as modified by Dr. Ted Sammis at New Mexico State University (1985). This equation requires daily weather data consisting of maximum and minimum temperatures, relative humidity, solar radiation, and wind.

12 ET Toolbox Calculations

A vegetation coefficient (KC) is applied to the Eto to determine the daily ET in inches using the formula:

$$ET = KC\ x\ Eto$$

where Eto is the Reference ET as calculated by the Penman equation. Refer to Penman Reference ET Calculation (section 11). Graphs of vegetation coefficients are presented as Growing Degree Days (GDD). Refer to Vegetation Coefficients (section 13).

The GDD's are accumulated heat that will contribute to plant growth and development from planting to harvest, or bud break to defoliation. The average method was chosen in New Mexico (King, et al., 2000) for determination of GDD using:

$$GDD = ((daily\ max\ temp + min\ temp)/2) - base\ temp$$

The maximum and minimum temperatures are replaced with cutoff temperatures when the limits are exceeded. In order to avoid negative GDD, the base temperature is set to the minimum temperature where growth stops.

Crop coefficients were taken from King et al. (2000) and Jensen (1998). The coefficients for Salt Cedar and Cottonwood (predominate riparian types) were received from Dr. Salim Bawazir, NMSU (personal correspondence) as a result of extensive field studies in 1999 at the Bosque Del Apache National Wildlife Refuge.

Dr. Jensen (1998) performed a study on open water evaporation for the Lower Colorado River. The monthly coefficients for open water in the Parker Dam to Imperial Dam reach along the Lower Colorado are being used for the Middle Rio Grande. Improved coefficients for open water and wet sands are forthcoming; from a on-going research studies at Elephant Butte Reservoir. Refer to Open Water Evaporation Estimates (section 15).

Monthly limits are applied to ET calculated at the Luis Lopez weather station. These limits are intended as a short term solution for adjusting high consumptive use in the Socorro, NM area due to clay soil types, requested by Jim Farmer of the Natural Resources Conservation Center in Socorro. The values (figure 17) are the maximum ET in inches allowed at the Luis Lopez weather station.

Computer processes were developed to collect all of the required data sets and calculate the Daily Consumptive Use (DCU) in acre feet for each vegetative type within each HRAP grid cell using:

$$Vegetative\ type\ DCU = ET\ x Acres\ /12$$

where Acres is the vegetative or open water acreage of the grid cell. Refer to Land Use Trend Analysis (section 14).

All of the acre feet values are summed to arrive at an estimated consumptive use for each grid cell. The NEXRAD estimated daily accumulated rainfall (in acre feet) is then subtracted.

$$Total\ Grid\ Cell\ DCU = Sum\ of\ Vegetativetype\ DCU's - Rainfall$$

$$River\ Reach\ DCU = Sum\ of\ Total\ Grid\ Cell\ DCU\ values\ within\ the\ river\ reach.$$

$$Diversion\ DCU = Sum\ of\ Total\ Grid\ Cell\ DCU\ values\ within\ the\ diversion.$$

The DCU values in acre feet per day are also converted to flow in cubic feet per second (cfs) for use by water managers and in the URGWOM, where:

$$cfs = acre\ feet/1.98347$$

Toolbox.

13 Vegetation Coefficients and Related Data

The following tables separate the classifications into Agriculture, Riparian, Open Water, and Urban. The start (plant) and stop (harvest) dates are used as beginning and ending points in the ET calculations. Current classification sources are the 1992/93 Land Use Trend Analysis (LUTA) and 2000 IKONOS (IKONOS).

Clicking on a FIG (figure) provides an x-y plot of the coefficients (KC) vs the Growing Degree Days (GDD) or Month, including a tabulation of the data. If a GDD plot, the polynomial function and GDD limits are also provided.

The vegetation classifications with "None" dates are currently not used in the ET Toolbox because they were not classified within LUTA or IKONOS. All other classifications with real dates are used in the ET Toolbox. Note that the IKONOS is used only in River Reach 7.

The LUTA classifications of Bosque, Riparian Shrub, and Riparian Woodland use an average of the Cottonwood and Salt Cedar coefficients, except in May, June, and July when the coefficient is set to 1.00. This was suggested by Dr. Samlim Bawazir of the New Mexico State University.

Numerous classifications do not have developed coefficients. In these cases, substitute coefficients are used until research is completed. Example: The Corn coefficients are used for Chili Peppers. It is extremely difficult to pick the appropriate substitution especially with the riparian classifications that have mixtures of vegetations. Improvements to these coefficients will greatly enhance the accuracy of water use estimates.

Table 2: Agricultural Classifications

AGRICULTURAL	FIG	SUBSTITUTE	PLANT (START) DATE	HARVEST (STOP) DATE	CLASS SOURCE
Alfalfa	20	-	Jan. 1	Oct. 20	LUTA
Chile Peppers	27	Corn	Apr. 29	Nov. 20	LUTA
Corn	27	-	Apr. 29	Nov. 20	LUTA
Cotton	23	-	None	None	None
Grapes	24	-	Apr. 1	Oct. 20	LUTA
Melons	25	-	Apr. 1	Sep. 1	LUTA
Misc. Fruit	26	-	Jan. 1	Dec. 31	LUTA
Misc. Vegetables	27	Corn	Apr. 29	Nov. 20	LUTA
Nursery Stock	28	-	Jan. 1	Dec. 31	LUTA
Oats	29	Spring Barley	Apr. 10	Aug. 10	LUTA
Pasture Grass	39	Turf-Park	Mar. 15	Oct. 20	LUTA
Pecan 1000*	31	-	None	None	None
Pecan 2000*	32	-	None	None	None
Pecan 3000*	33	-	None	None	None
Pecan 4000*	34	-	None	None	None
Pinto Beans	35	-	None	None	None
Sorghum	36	-	May 17	Dec. 20	LUTA
Spring Barley	37	-	None	None	None
Tree Fruit	38	-	Jan. 1	Dec. 31	LUTA
Wheat†	40	-	Apr. 10	Aug. 10	LUTA
Wheat>1300 GDD†	41	-	Apr. 10	Aug. 10	LUTA

*(1000, 2000, 3000, and 4000 are tree trunk diameter (cm) x number of trees per hectare)

†(when the Growing Degree Days sum exceeds 1300, the Wheat>1300 is used)

Table 3: Riparian Classifications

RIPARIAN	FIG	SUBSTITUTE	PLANT (START) DATE	HARVEST (STOP) DATE	CLASS SOURCE
Bosque*	43	-	Apr. 5	Nov. 21	LUTA
Cottonwood	44	-	Apr. 5	Nov. 21	IKONOS
Cottonwood Bosque	44	Cottonwood	Apr. 5	Nov. 21	IKONOS
Cottonwood/RO/WM†	44	Cottonwood	Apr. 5	Nov. 21	IKONOS
Cottonwood/SC/WM‡	44	Cottonwood	Apr. 5	Nov. 21	IKONOS
Grassland	44	Cottonwood	Mar. 15	Oct. 20	IKONOS
Marsh	48	-	Jan. 1	Dec. 31	LUTA
Misc. Grass	39	Turf-Park	Jan. 1	Dec. 31	LUTA
Riparian Shrub§	45	Bosque	Apr. 5	Nov. 21	LUTA
Riparian Woodland§	46	Bosque	Apr. 5	Nov. 21	LUTA
Russian Olive/WL¶	44	Cottonwood	Apr. 5	Nov. 21	IKONOS
Salt Cedar	47	-	Apr. 5	Nov. 21	LUTA
Salt Cedar/RO/WM†	47	Salt Cedar	Apr. 5	Nov. 21	IKONOS
Salt Cedar/WL¶	47	Salt Cedar	Apr. 5	Nov. 21	IKONOS
Shrubland	44	Cottonwood	Apr. 5	Nov. 21	IKONOS
Sparce Vegetation	44	Cottonwood	Mar. 15	Oct. 20	IKONOS
Willow	44	Cottonwood	Apr. 5	Nov. 21	IKONOS
Wetland	48	Marsh	Jan. 1	Dec. 31	IKONOS

*(An average of Cottonwood and SaltCedar, except 1.0 in May, June, and July)
†(RO = Russian Olive/WM = Willow Mix)
‡(SC = Salt Cedar/WM = Willow Mix)
§(No average of Cottonwood and SaltCedar)
¶(WL = Woodland)

Table 4: Open Water Classifications

OPEN WATER	FIG	SUBSTITUTE	PLANT (START) DATE	HARVEST (STOP) DATE	CLASS SOURCE
Open Water	42	-	Jan. 1	Dec. 31	LUTA
Water or Wet Soil	42	Open Water	Jan. 1	Dec. 31	IKONOS

Table 5: Urban Classifications

URBAN	FIG	SUBSTITUTE	PLANT (START) DATE	HARVEST (STOP) DATE	CLASS SOURCE
Turf-Golf	39	Turf-Park	Mar. 15	Oct. 20	None
Turf-Park	39	-	Mar. 15	Oct. 20	LUTA
Urban Irrigation	39	Turf-Park	Mar. 15	Oct. 20	LUTA

14 GIS Land and Open Water Classification

River front near the Bosque riparian research site.

Several Geographic Information System (GIS) vegetation data sets that cover portions of the area were evaluated. The Middle Rio Grande Land Use Trend Analysis (LUTA) GIS data base for 1992/93 is the current land use resource for URGWOM river reaches 1-5 (from Cochiti Dam to the San Acacia Diversion Dam). Data from a 1998 Bureau of Reclamation riparian vegetation classification were used for river reach 6 (from San Acacia to San Marcial). Reach 6 also includes the Middle Rio Grande Conservancy District's Socorro Division, and the Bosque del Apache National Wildlife Refuge. An IKONOS satellite GIS was used for river reach 7. The GIS data were transposed to the nominal 4 km x 4 km HRAP grid cell resolution for use in the ET Toolbox with the NEXRAD-based 24-hr rainfall estimates. An important component of the ET Toolbox is determination of the vegetative growth acreage of agricultural crops, riparian vegetation, and open water in each of the 4 km x 4 km HRAP grid cells. These data are then applied to the empirically derived ET (Refer to ET Toolbox Calculations) to produce a daily volumetric water requirement for each HRAP cell.

Additional year 2002 riparian GIS efforts by both the Utah State University and the Endangered Species Collaborative Program should be available by September, 2003.

There is a need to develop a methodology for updating the GIS vegetation and open water indexing data to detect changes and update the ET Toolbox at least once during each annual growing season. The constraints are that the technology used must by cost permissive, timely, and sufficiently accurate (e.g. 90in water resources management.

14.1 River Reaches 1-5 (LUTA)

The Middle Rio Grande Water Assessment - Middle Rio Grande Land Use Trend Analysis Geographic Information System Data Base - Supporting Document Number 13

(1997) - for 1992/93 was chosen for river reaches 1-5. This data base contains the most currently available analysis performed within these upper reaches of the river system from Cochiti Dam to San Acacia Dam.

The purpose of the LUTA was to identify and quantify land use trends in the Albuquerque basin, New Mexico, over the last 58 years on those lands that significantly impact groundwater resources. Historic and current aerial photography and 1992 Landsat Thematic Mapper satellite imagery were used as primary sources for compiling the LUTA GIS database. Reclamation and the City of Albuquerque identified four periods of time for the LUTA: 1935, 1954/55, mid 1970's, and 1992/93. A GIS database was constructed for each of the four time periods.

Coverages from the LUTA GIS were transformed to the 4 km x 4 km HRAP grid cells using GIS tools provided by members of the Civil, Agricultural, and Geological Engineering Department at the New Mexico State University. Results, which were first separated into four counties, then merged and placed into files acceptable to the ET Toolbox computer programs. Approximately 127 HRAP grid cells from the LUTA are included in the ET Toolbox.

14.2 River Reach 6 (USBR, MRGCD, BdA)

River reach 6 includes the area from San Acacia Dam to the San Marcial gage below the Bosque del Apache Wildlife Refuge. A Reclamation aerial photography GIS study completed in 1999 is used to get the riparian growth classification for this reach. Agricultural acreage for San Acacia Dam to the northern edge of the Bosque del Apache is assumed to be 23of 1985 through 1997. Personnel at the Refuge provided agricultural acreage for the Refuge. Reach six added 31 HRAP grid cells to the study. The total of 158 HRAP grid cells, at approximately 4,000 acres each, provides ET Toolbox coverage to about 632,000 acres.

14.3 River Reach 7 (IKONOS)

The riparian component of an IKONOS satellite 4-metar multi spectral resolution land use data set from July 2000 is used in the ET Toolbox for river reach 7 commencing in 2002. The riparian IKONOS was acquired from the MRGCD and the New Mexico Interstate Stream Commission. This IKONOS riparian GIS study was limited to areas within the riverside drains; therefore it can not be used throughout the ET Toolbox range from Cochiti Dam to San Marcial gage. (reaches 1 through 6).

15 Open Water Evaporation Estimates

The evaporation from open water and wet sands contributes significantly to the water depletion in the Middle Rio Grande valley. Research is underway to determine and measure the evaporative demand by using LIght Detection And Ranging (LIDAR) and other technologies. A consortium of groups and programs are at work on this research, consisting of the Bureau of Reclamation, Los Alamos National Labs, and New Mexico State University, and Utah State University, and University of Iowa, and and others. A year long effort was initiated in 2001 on Elephant Butte reservoir to determine the actual evaporation off the lake surface. A tower was constructed and instrumented, and the Los Alamos Raman LIDAR was on the lake in September 2001 to determine the extent of the measurements by the tower instrumentation. Click here to learn about the similar Tamarisk research study. The results of this research should provide a means of determining an evaporative coefficient, similar to crop coefficients, that can be applied to to a reference ET equation. Real-time reservoir area based on height versus surface area tables can then be used in the calculation of daily evaporative use.

Meanwhile, coefficients developed by Dr. Jensen (1998) on open water evaporation for the Lower Colorado River in the Parker Dam to Imperial Dam reach are used for the Middle Rio Grande.

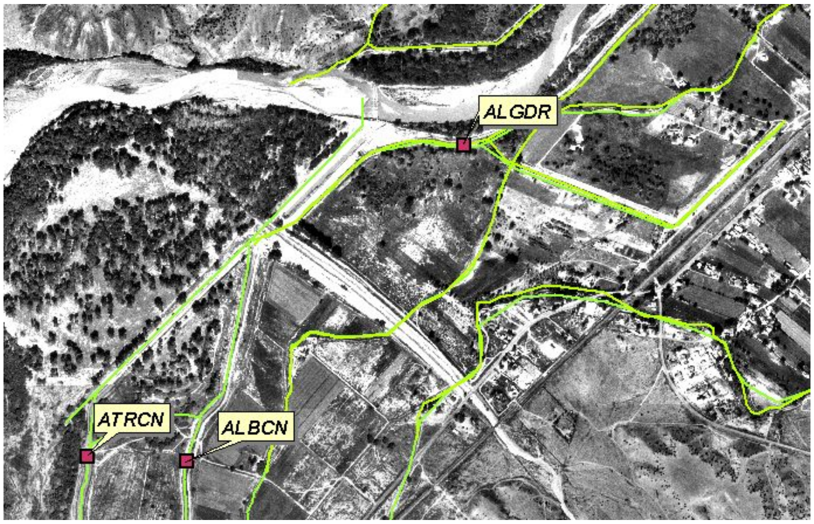
16 Interface with RiverWare

ET Toolbox files for each river reach (currently 7) are available for the URGWOM team to access at around 6:45 AM MST each day. The river reach boundaries are listed in the following table. These files contain HRAP cell-by-cell daily rainfall (inches), and consumptive values (acre-feet) for all agricultural, riparian, and urban vegetation classifications, and the open water classification for the day. To get the net water use requirement, the rainfall must be converted to acre-feet and subtracted from the consumptive use (Refer to ET Toolbox Calculations).

River Reach 1	Cochiti Dam gage to San Felipe gage
River Reach 2	Jemez River above gage below Jemez Canyon Dam
River Reach 3	San Felipe gage to Central Avenue gage
River Reach 4	Central Avenue gage to Bernardo gage
River Reach 5	Bernardo gage to San Acacia gage
River Reach 6	San Acacia gage to San Marcial gage (includes the Bosque Del Apache)
River Reach 7	San Marcial gage to north end of Elephant Butte Reservoir
River Reach 8	North end of Elephant Butte to gage below Elephant Butte Dam (future)

A sample ET Toolbox file (figure 49 W) containing all data for the first HRAP grid cell in River Reach 3 for the month of January is shown. (The Internet version shows all data for the current year.) Here (figure 50 W) is description of the ET Toolbox file. The data for the last three lines under each grid cell are forecast values based on the National Center for Environmental Prediction (NCEP) 12-km grid Eta model. The tasks of developing the Data Management Interfaces (DMIs) between the ET Toolbox HRAP cells data files, the Hydrologic Engineer Center - Data Storage System (HEC-DSS), and RiverWare were apparently accomplished by the URGWOM team.

17 Stream Flow Gages



Gage Station Products in the Angostura Dam Area.

As an enhancement to the ET Toolbox, users at the Middle Rio Grande Conservancy District and USBR requested near real-time graphs and text of stream flow conditions throughout the valley. This allows direct comparison of consumptive use estimates and stream flow, considering an approximate five day lag for water released at Cochiti Dam to arrive at the San Marcial gage. District personnel developed schematics of the diversions and return flows.

The stream flow information is acquired from the MRGCD stream gage network. Two data sets are received. The first set is MRGCD managed gage station and USBR pumping station data transmitted from the gage to the district office via radio telemetry. This set is then automatically received into the ET Toolbox from the MRGCD stream gage network via FTP at 15 and 45 minutes past each hour.

The second set is USGS managed gage station data received at the district office via the US Corps of Engineers who get it from the USGS. These USGS data are provided in 15-minute intervals, but to be consistent with the MRGCD data which are received into the ET Toolbox in 30-minute intervals, the minute 15 and 45 are ignored. The USGS data is automatically received into the ET Toolbox from the MRGCD via FTP at 20 minutes after each of the following hours: midnight, 4:00 AM, 8:00 AM, noon, 4:00 PM, and 8:00 PM.

All of the data are assembled into text files and plots; in some instances combining data for valley cross sections and operations. These data are best viewed from the MRGCD North and South Schematics, available by clicking on Stream Flow Data from the inter-active ET Toolbox window. (figure 1 W) This pops-up a Stream Flow Products window. (figure 51 W)

From there, click on either of the boxes labeled MRGCD North Schematic (figure 52 W) or MRGCD South Schematic. (figure 53 W)

The gage naming criteria differ between the MRGCD, USBR, and USGS managed stations. The MRGCD uses a three character gage name followed by DV (diversion), CN (canal), DR (drain), WW (waste way), UP (Rio Grande above Isleta Dam), DN (Rio Grande below Isleta Dam), and XC (cross section). Pumping stations managed by the USBR use a three character gage name followed by PS (pumping station). The USGS uses the Standard Hydrometeorological Exchange Format (SHEF) convention. This is a three character gage name followed by the 1st character of the state name, followed by a number representing the states alphabetical order. New Mexico (N) is the 5th state (5). Therefore all USGS gages in New Mexico are identified by N5 in the 4th and 5th character positions. Colorado is C2.

The schematics are updated every 30-minutes, as noted by the posted date and time at the bottom. All times are Mountain Standard Time (MST) throughout the year. The schematics show the inflows and outflows throughout the MRGCD. Green boxes are MRGCD gages, yellow boxes are USGS gages, and orange boxes are USBR pumping stations.

Values posted in the boxes are the latest discharges in cfs. No value in a box means the stream flow gage network has not been established. Clicking on a box with a value, or N/A, pops-up a graph containing two charts. The bottom chart shows the height (stage) ot the gage in feet and the top shows the discharge (stream flow) in cfs. A table to the right of the graph provides the year-to-date gage information. N/A means the data for the chart are missing.

Valley Cross Sections on the left of the north schematic represent river reaches 1,3,4,5,and 6 from Cochiti to San Marcial. These cross sections contain summations of individual gages (in some cases both MRGCD and USGS) with a trace for each. The gaging information table on the right shows the data for each gage, the total, and the daily average. The daily consumptive use chart at the bottom allows comparison of stream flow and consumptive use, for all cross sections except San Marcial. The comparable reach summary report is shown on the right. Click here (figure 54 W) for an example of a valley cross section.

Irrigation diversions on the right of the north schematic represent the four district diversion points. The Cochiti diversion is a summation of USGS gages at the two canals below Cochiti Dam.

Clicking on the white triangles found on many of the pop-up windows throughout the ET Toolbox provides real-time Internet links to USGS gage graphs and text data. Click (here) for an example.

Clicking on the upside-down white triangles from the Stream Flow Products window (figure 51 W) pops-up area-wide gage station products. Included in these are plots and tables of some of the same data that are on the schematics, and some reservoir storage and elevation data from the USGS. Also available are combinations of stream data for the Rio Chama Operations (RCOPS), Middle Valley Operations (MVOPS), and Middle Valley Flows (MVFLO). Some images of gage locations are shown. These products, from the upside-down white triangles, were developed before implementation of the schematics. Click (figure 55 W) here for an example.

18 Historic ET Toolbox Processing - 1975 to 1998

At the request of the URGWOM team, historic consumptive use values were processed to satisfy a requirement of determining agricultural and riparian water depletions in each of the six river reaches. The results of this study were used to calibrate the URGWOM.

Years 1984 through 1998 were processed using a combination of the Alcalde and Los Lunas weather stations. Temperature and relative humidity from the Los Lunas station and solar radiation and wind from the Alcalde station were used to calculate the Penman reference ET.

Years 1975 through 1983 were processed differently. For these years there were no data from Alcalde, and only temperature and precipitation data were available at Los Lunas. Therefore, a monthly comparison of temperature and precipitation was made with years 1984 through 2000. Daily relative humidity, solar radiation, and wind data from the closest matched month in the period 1984 through 2000 were then used to calculate the Penman reference ET. An Excel spread sheet has been developed that shows the Los Lunas precipitation and temperature data, and a comparison of monthly precipitation and average temperatures for each year 1975 through 1983, with 1984 through 2000. Click here) for the spread sheet. Page seven of the spread sheet contains documentation of the procedures used.

Years 1999 through the last most current year used temperature, relative humidity, solar radiation, and wind data from various weather stations for calculating the Penman reference ET. The stations were assigned to specific 4 km x 4 km HRAP grid cells within each reach:

1999	Reaches 1 and 2	Alcalde
	Reach 3	Rio Grande Nursery (NMCC)
	Reach 4	Los Lunas
	Reach 5	Boy's Ranch
	Reach 6	North Bosque
2000	Reach 1	Pena Blanca and Angostura
	Reach 2	Angostura
	Reach 3	Angostura, Rio Grande Nursery, and Albuquerque Golf Course (NMCC)
	Reach 4	Bosque Bar (MRGCD), Rio Grande Nursery, Los Lunas, Jarales, and Boy's Ranch
	Reach 5	Boy's Ranch
	Reach 6	Luis Lopez, North Bosque, and South Bosque
2001	Reach 1	Pena Blanca and Angostura
	Reach 2	Angostura
	Reach 3	Angostura, Rio Grande Nursery, and Albuquerque Golf Course (NMCC)
	Reach 4	Bosque Bar (MRGCD - through Dec 6), Rio Grande Nursery, Los Lunas, Jarales, and Boy's Ranch
	Reach 5	Boy's Ranch and San Acacia
	Reach 6	San Acacia, Luis Lopez, North Bosque, and South Bosque
2002	Reach 1	Pena Blanca and Angostura
	Reach 2	Angostura
	Reach 3	Angostura, Rio Grande Nursery, and Albuquerque Golf Course (NMCC)
	Reach 4	Rio Grande Nursery, Los Lunas, Jarales, and Boy's Ranch
	Reach 5	Boy's Ranch and San Acacia
	Reach 6	San Acacia, Luis Lopez, North Bosque, and South Bosque
	Reach 7	South Bosque

Occasionally data from weather stations were not available. In these cases interim substitutions were made while repairs were underway, or permanent replacements were made if new or nearby stations were available.

In all historic processing through 1998, only weather station precipitation data were used since NEXRAD data were not collected for the ET Toolbox until 1999. Therefore, the historic data posted on the Web site for 1999 through the last most complete year uses NEXRAD precipitation. This is an important item to note when comparing 1975 through 1998 precipitation data with 1999 through current precipitation data.

Numerous reruns of the historic ET Toolbox processing for 1975 through 1998 have occurred. The more recent was in February 2003 to correct problems with the agricultural acreage and precipitation in reach 6.

For these historic calculations, the vegetative acreage from the 1992/93 LUTA for reaches 1 through 5 were used, as well as the combinations of data sources for reach 6. Refer to GIS Land and Open Water Classification (section 14).

The same crop coefficients and Penman Reference ET Equation were used. The only variance from year-to-year was the weather data.

The year 2001 ends on December 6 due to the Department of the Interior shutdown of Internet communications.

19 Data Flow - Computer Processing

There are many data sets used in the ET Toolbox that are acquired either hourly or daily through the use of C-SHELL scripts. These scripts are run on a Sun Ultra 60 Computer Workstation using the Solaris 8 UNIX operating system. The computer is located in the Bureau of Reclamation's Technical Service Center, Water Resources Services Division, at the Denver Federal Center, Lakewood, Colorado. The scripts call various computer programs written mostly in FORTRAN, although some C and Python programming is also used. This documentation will be completed in 2003. The data acquisition and management of the NEXRAD data is not documented here (possibly in the future).

Abbreviations used in the flow diagrams are:

WX	Weather Station
Web	World-Wide Web (Internet)
FTP	File Transfer Protocal
SHEF	Standard Hydrologic Exchange Format
WGRFC	West Gulf River Forecast Center
Eta	A weather forecast model run from the National Center for Environmental Prediction
ET	Evapotranspiration
NEXRAD	NEXt generation RADar
DOS	Disk Operating System

Click on the following subjects to access flow diagrams of the function of each major script, called program, and related data flow. (under development)

Weather (Real-Time and Forecast)
Gage (Real-Time Stream flow and Reservoir Status)
ET Toolbox (Reference ET, Crop ET, ET Charts, ET Toolbox, Plotting)
Miscellaneous (Acres Processing and Reporting, and other processing)

A more detailed document is being developed for the ET Toolbox program developers and managers to help guide them through the complex operation of the computer system.

20 ET Toolbox Research

Future ET Toolbox research could include studies to:

1. Implement daily open water calculations with actual daily areal extent updates (the FLO-2D model is under consideration)
2. Revise evaporation coefficients based on results of open water field studies
3. Improve the riparian vegetation ET coefficients and make other equation changes based on the results of the ET field studies
4. Determine if adding soil moisture fields from Land Surface Models and observations, and soil types and slope, can be used in the ET Toolbox to improve the efficiency of water management
5. Improve estimates of effective precipitation using soil types and slope, and soil moisture
6. Improve the situation analysis matrix with predicted stream flow data

21 References

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4. Sammis, T.W., C.L. Mapel, D.G. Lugg, R.R. Lansford, J.T. McGuckin, 1985:
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5. Predicted Using Growing Degree Days. Transactions of the ASAE (American Society of Agricultural Engineers) 28(3), pp. 773-780.

22 FIGURES

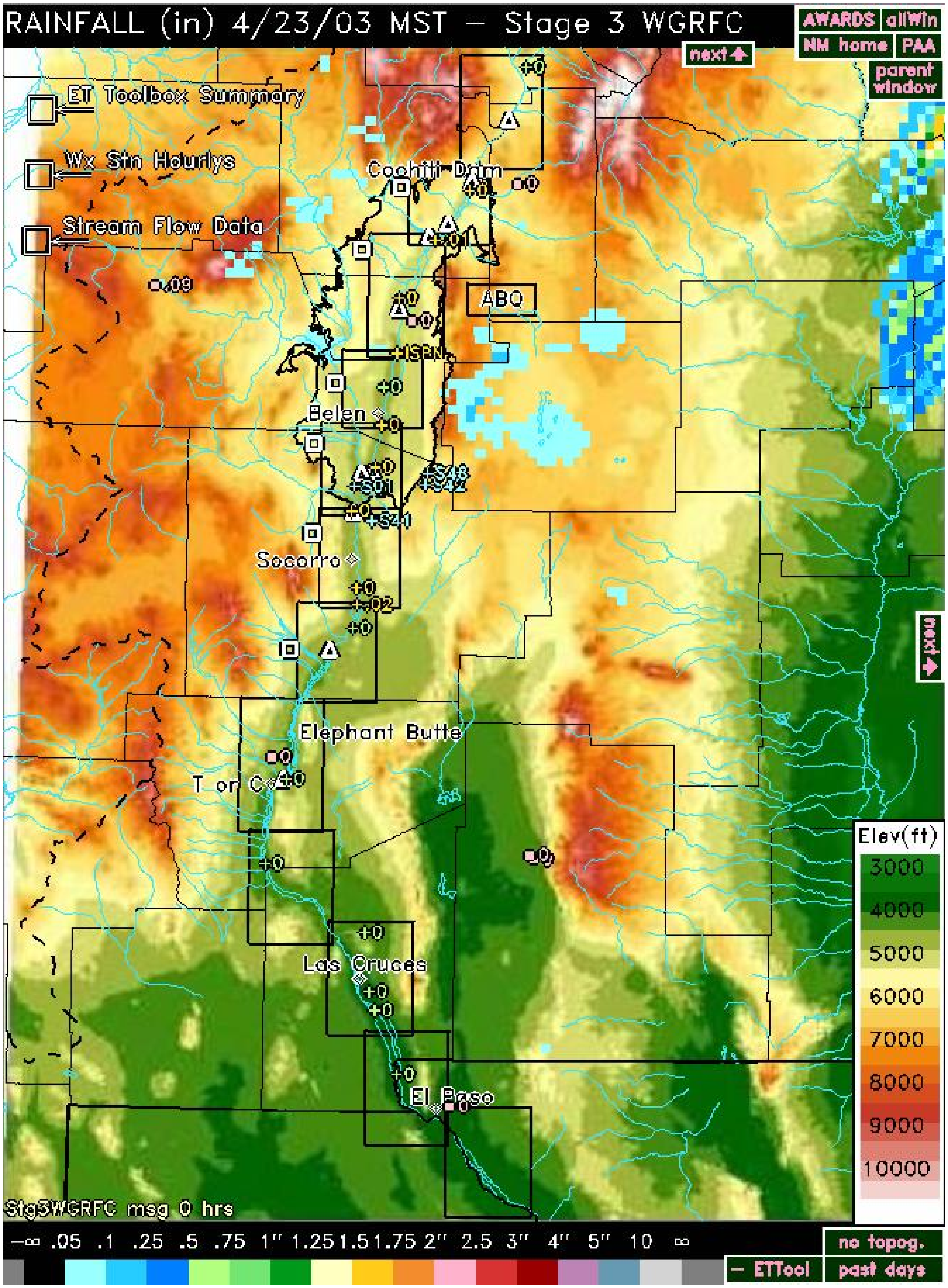

Figure 1: Colored Topography Inter-active ET Toolbox Window

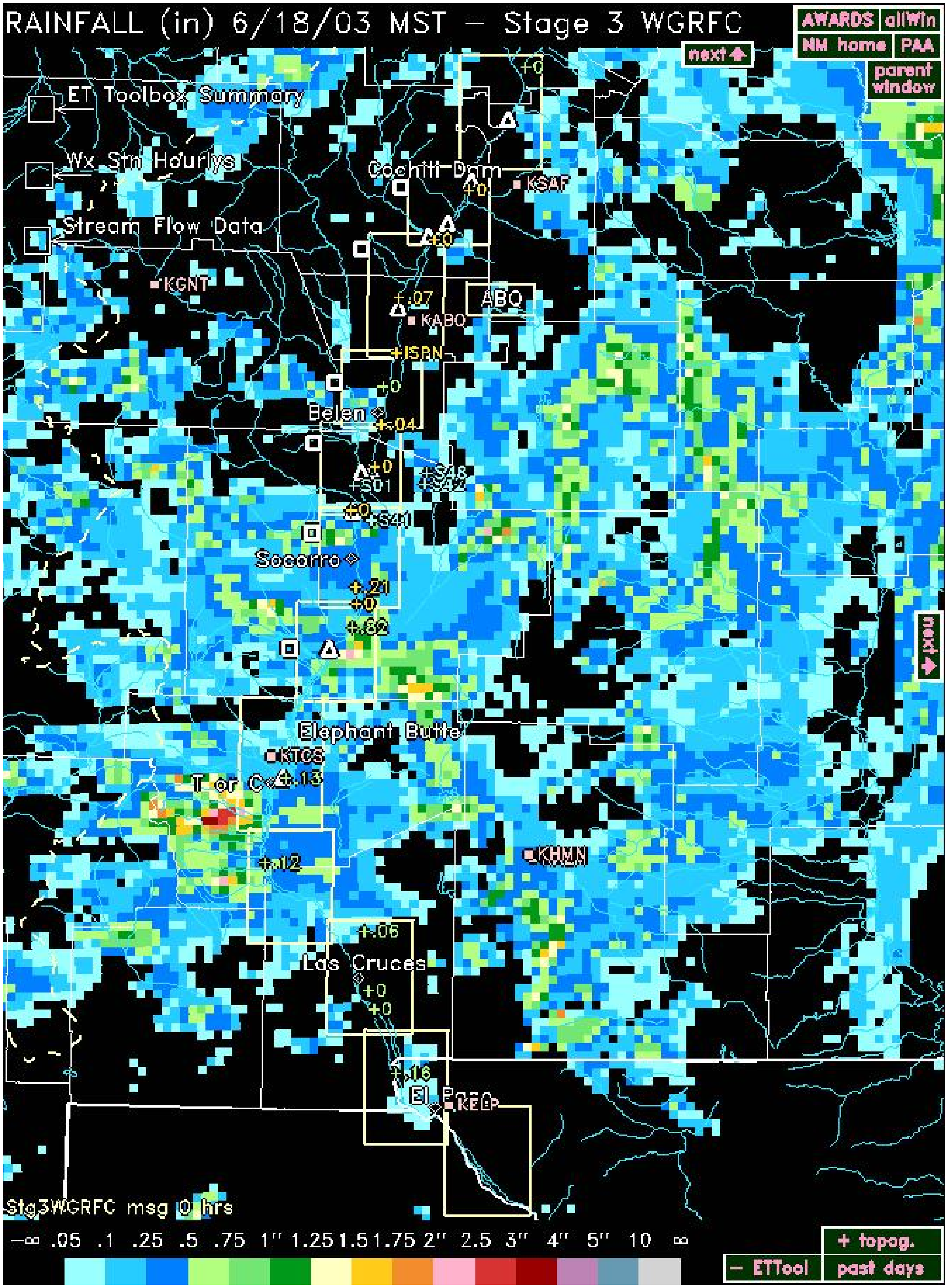

Figure 2: No Topography Inter-active ET Toolbox Window

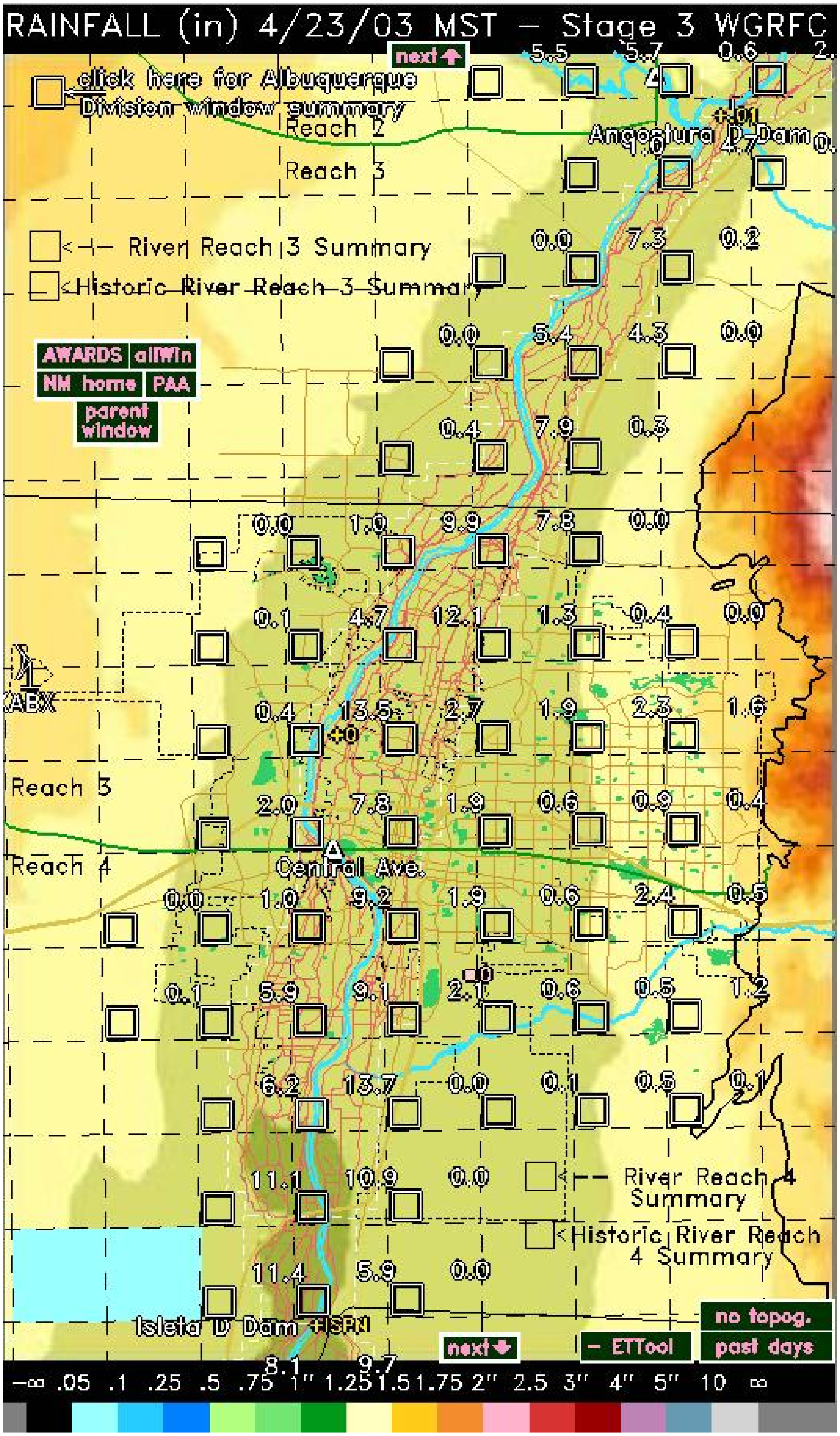

Figure 3: MRGCD Angostura Division (Diversion)

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```
            ET TOOLBOX CELL SUMMARY  (UNDER DEVELOPMENT)

                     Window named: Greater Albuquerque

                     Cell number: 103x305

                     Vegetation classification: LUTA  1992/93

                     Weather station: Candelaria Farms Station - MRGCD

     ET TOOLBOX classes (ag. + rip. + open water + urb.):     1803.0 acres

         (Daily URGWOM Water Use = Daily Consumptive Use Total - Rain)
```

2003 Month Day	F M	Daily Consumptive Use: Total CFS	Agriculture CFS	Riparian CFS	Open Water CFS	Urban CFS	Daily Rain CFS	Daily URGWOM Water Use: Total CFS	5-Day Avg. CFS	10-Day Avg. CFS	Total URGWOM Water Use To-Date Since Jan. 1, 2003 AC-FT
Apr. 26	E	15.4	7.1	3.2	3.1	1.9	0.0	15.4	12.3	11.5	568.5
Apr. 25	E	14.3	6.6	3.1	2.8	1.8	0.0	14.3	11.2	10.9	537.9
Apr. 24	E	12.2	5.6	2.6	2.5	1.5	0.0	12.2	10.7	10.2	509.6
Apr. 23		6.8	3.2	1.4	1.4	0.8	0.0	6.8	10.4	9.9	485.4
Apr. 22		12.6	5.8	2.7	2.6	1.5	0.0	12.6	10.8	10.3	471.9
Apr. 21		10.0	4.5	2.2	2.1	1.2	0.0	10.0	10.7	10.0	447.1
Apr. 20		12.0	5.6	2.4	2.5	1.5	0.0	12.0	10.6	9.9	427.2
Apr. 19		10.7	4.9	2.3	2.2	1.4	0.0	10.7	9.7	9.4	403.5
Apr. 18		8.6	4.0	1.8	1.8	1.1	0.0	8.6	9.5	9.1	382.3
Apr. 17		12.0	5.6	2.4	2.5	1.5	0.0	12.0	9.8	9.1	365.2
Apr. 16		9.5	4.4	1.9	2.0	1.2	0.0	9.5	9.2	8.6	341.3
Apr. 15		7.6	3.5	1.5	1.6	1.0	0.0	7.6	9.1	8.4	322.6
Apr. 14		9.5	4.4	1.9	2.0	1.2	0.0	9.5	9.2	8.6	307.5
Apr. 13		10.6	4.9	2.1	2.3	1.4	0.0	10.6	8.8	8.4	288.7
Apr. 12		9.0	4.2	1.7	1.9	1.2	0.0	9.0	8.3	8.2	267.7
Apr. 11		9.0	4.2	1.7	1.9	1.2	0.0	9.0	8.0	8.0	249.9
Apr. 10		7.8	3.7	1.3	1.8	1.1	0.0	7.8	7.6	8.1	232.2
Apr. 9		7.8	3.7	1.3	1.8	1.1	0.0	7.8	8.0	8.0	216.7
Apr. 8		7.7	3.7	1.3	1.7	1.1	0.0	7.7	8.0	8.1	201.2
Apr. 7		7.7	3.7	1.3	1.7	1.1	0.0	7.7	8.2	8.0	186.0
Apr. 6		7.2	3.4	1.3	1.6	1.0	0.0	7.2	8.1	7.6	170.7
Apr. 5		9.7	4.6	1.5	2.2	1.4	0.0	9.7	8.5	7.5	156.4
Apr. 4		7.7	3.9	0.9	1.8	1.2	0.0	7.7	8.1	7.3	137.3
Apr. 3		8.7	4.3	1.0	2.1	1.3	0.0	8.7	8.2	7.3	122.1
Apr. 2		7.2	3.7	0.8	1.7	1.1	0.0	7.2	7.8	7.1	104.9
Apr. 1		9.2	4.6	1.1	2.2	1.4	0.0	9.2	7.2	7.1	90.6
Mar. 31		7.6	3.8	0.9	1.8	1.2	0.0	7.6	6.5	6.9	72.4
Mar. 30		8.2	4.0	0.9	2.0	1.2	0.0	8.2	6.5	6.1	57.5
Mar. 29		6.9	3.5	0.8	1.6	1.1	0.0	6.9	6.4	0.4	41.3
Mar. 28		3.9	2.0	0.4	0.9	0.6	0.0	3.9	6.5	-0.6	27.6
Mar. 27		5.9	2.9	0.6	1.4	0.9	0.0	5.9	7.0	-6.3	19.8
Mar. 26		7.5	3.8	0.8	1.8	1.2	0.0	7.5	7.2	-6.4	8.2
Mar. 25		7.7	3.9	0.8	1.8	1.2	0.0	7.7	5.7	-7.2	-6.6
Mar. 24		7.4	3.8	0.8	1.8	1.2	0.0	7.4	-5.7	-7.4	-21.9
Mar. 23		6.6	3.3	0.7	1.6	1.1	0.0	6.6	-7.7	-7.8	-36.6
Mar. 22		6.9	3.5	0.7	1.7	1.1	0.0	6.9	-19.7	-8.0	-49.7
Mar. 21		2.9	1.5	0.3	0.7	0.5	3.0	-0.1	-20.1	-8.3	-63.4
Mar. 20		4.0	2.0	0.4	1.0	0.6	53.1	-49.1	-20.1	-8.0	-63.2
Mar. 19		1.0	0.6	0.1	0.2	0.2	3.8	-2.8	-9.1	-2.8	34.1
Mar. 18		2.9	1.5	0.3	0.7	0.5	56.2	-53.2	-7.9	-2.2	39.7
Mar. 17		4.8	2.4	0.4	1.2	0.8	0.0	4.8	3.7	3.5	145.1
Mar. 16		2.4	1.2	0.2	0.6	0.4	2.3	0.1	3.4	3.3	135.6
Mar. 15		5.7	2.9	0.5	1.4	0.9	0.0	5.7	4.0	3.5	135.4
Mar. 14		3.3	1.6	0.3	1.4	0.0	0.0	3.3	3.6	3.2	124.0
Mar. 13		4.4	2.1	0.4	1.9	0.0	0.0	4.4	3.5	3.0	117.4
Mar. 12		3.4	1.6	0.3	1.5	0.0	0.0	3.4	3.3	2.8	108.7
Mar. 11		3.3	1.6	0.3	1.4	0.0	0.0	3.3	3.1	2.7	101.8
Mar. 10		3.4	1.6	0.3	1.5	0.0	0.0	3.4	3.0	2.5	95.3
Mar. 9		3.0	1.5	0.3	1.3	0.0	0.0	3.0	2.8	2.2	88.5
Mar. 8		3.1	1.5	0.3	1.4	0.0	0.0	3.1	2.5	2.0	82.6
Mar. 7		2.7	1.3	0.2	1.2	0.0	0.0	2.7	2.4	0.4	76.5
Mar. 6		3.0	1.5	0.2	1.3	0.0	0.0	3.0	2.2	0.1	71.1
Mar. 5		2.1	1.0	0.2	1.0	0.0	0.0	2.1	1.9	-1.3	65.3
Mar. 4		1.9	1.0	0.1	0.8	0.0	0.0	1.9	1.5	-1.3	61.1
Mar. 3		2.2	1.1	0.1	1.0	0.0	0.0	2.2	1.5	-1.2	57.3
Mar. 2		2.0	1.0	0.1	0.9	0.0	0.0	2.0	-1.5	-1.2	52.9
Mar. 1		1.3	0.6	0.1	0.6	0.0	0.0	1.3	-2.1	-3.5	49.0

```
Irrigated Ag acreage =   705.5
                Riparian acreage =    681.4 (Includes Bosque)
                          Open Water acreage =    233.3
                                        Urban acreage =    182.8
                                             Total (ag. + rip. + open water + urb.) =     1803.0 acres
Fallow acreage =      2.7
Idle acreage =       70.5
```

Thursday April 24, 2003 GABQ.etsum.103.305.txt 1/1

Figure 4: Grid Cell Summary Example

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Apr 30, 03 10:54 **GABQ.etcrop.103.305.txt** Page 1/1

```
                     ET TOOLBOX CELL DETAILS  (UNDER DEVELOPMENT)

                      Greater Albuquerque

                      Vegetation classification: LUTA  1992/93

                      Cell number: 103x305

                      Weather station: Candelaria Farms Station - MRGCD

                      Last 7 and 3 Forecast Day's URGWOM Water Use in Acre-Feet  (CFS)

Consumptive Use                                                          Forecast
---------------                              2003                  ------------------
 Crop        Acres   Apr.   Apr.   Apr.   Apr.   Apr.   Apr.   Apr.   Apr.   May    May
                      23     24     25     26     27     28     29     30     1      2
                     ----   ----   ----   ----   ----   ----   ----   ----   ----   ----
Alfalfa      377.4    3.8    5.3    6.0    6.6    6.3    5.7    6.9    8.8    8.5    9.1
PastGrass    262.6    2.4    3.5    3.9    4.2    3.9    3.5    4.4    5.5    5.0    5.5
Sorghum       40.2    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
Grapes        13.1    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
Urban Irr    141.4    1.3    1.9    2.1    2.2    2.1    1.9    2.4    3.0    2.7    3.0
Park/Golf     41.4    0.4    0.6    0.6    0.6    0.6    0.6    0.7    0.9    0.8    0.9
Rip. Wood     24.2    0.1    0.1    0.1    0.1    0.1    0.1    0.1    0.2    0.2    0.2
Rip. Shrub    20.2    0.1    0.1    0.1    0.1    0.1    0.1    0.1    0.2    0.2    0.2
Marsh         62.7    1.0    1.5    1.6    1.7    1.6    1.5    1.8    2.3    2.1    2.3
Open Water   233.3    2.7    3.9    4.3    4.7    4.5    3.9    4.9    6.2    5.8    6.4
Misc Grass    24.5    0.3    0.4    0.4    0.4    0.4    0.4    0.5    0.6    0.6    0.6
Tree Fruit     3.3    0.0    0.1    0.1    0.1    0.1    0.1    0.1    0.1    0.1    0.1
Nursery St     3.3    0.0    0.1    0.1    0.1    0.1    0.1    0.1    0.1    0.1    0.1
Oats           1.6    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
Misc Vegs      4.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
Bosque       549.8    1.4    2.3    2.8    2.8    2.8    2.8    3.2    4.1    4.1    4.6
            ------   ----   ----   ----   ----   ----   ----   ----   ----   ----   ----
  Totals    1803.0   13.5   19.6   22.1   23.6   22.6   20.4   25.1   31.8   30.2   32.9
                  (  6.8)(  9.9)( 11.2)( 11.9)( 11.4)( 10.3)( 12.7)( 16.1)( 15.3)( 16.6)

Agricul.     705.5    6.3    9.0   10.1   10.9   10.4    9.3   11.5   14.5   13.7   14.8
                  (  3.2)(  4.5)(  5.1)(  5.5)(  5.2)(  4.7)(  5.8)(  7.3)(  6.9)(  7.5)

Riparian     681.4    2.8    4.3    5.0    5.1    5.0    4.8    5.7    7.3    7.1    7.9
                  (  1.4)(  2.2)(  2.5)(  2.6)(  2.5)(  2.4)(  2.9)(  3.7)(  3.6)(  4.0)

Open Water   233.3    2.7    3.9    4.3    4.7    4.5    3.9    4.9    6.2    5.8    6.4
                  (  1.4)(  2.0)(  2.2)(  2.4)(  2.3)(  2.0)(  2.5)(  3.1)(  2.9)(  3.2)

Urban        182.8    1.7    2.4    2.7    2.9    2.7    2.4    3.0    3.8    3.5    3.8
                  (  0.8)(  1.2)(  1.4)(  1.5)(  1.4)(  1.2)(  1.5)(  1.9)(  1.8)(  1.9)

   NEXRAD
-------------
Rainfall Est.         0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0    0.0
                  (  0.0)(  0.0)(  0.0)(  0.0)(  0.0)(  0.0)(  0.0)(  0.0)(  0.0)(  0.0)

   URGWOM
-------------
Water Use            13.5   19.6   22.1   23.6   22.6   20.4   25.1   31.8   30.2   32.9
                  (  6.8)(  9.9)( 11.2)( 11.9)( 11.4)( 10.3)( 12.7)( 16.1)( 15.3)( 16.6)
```

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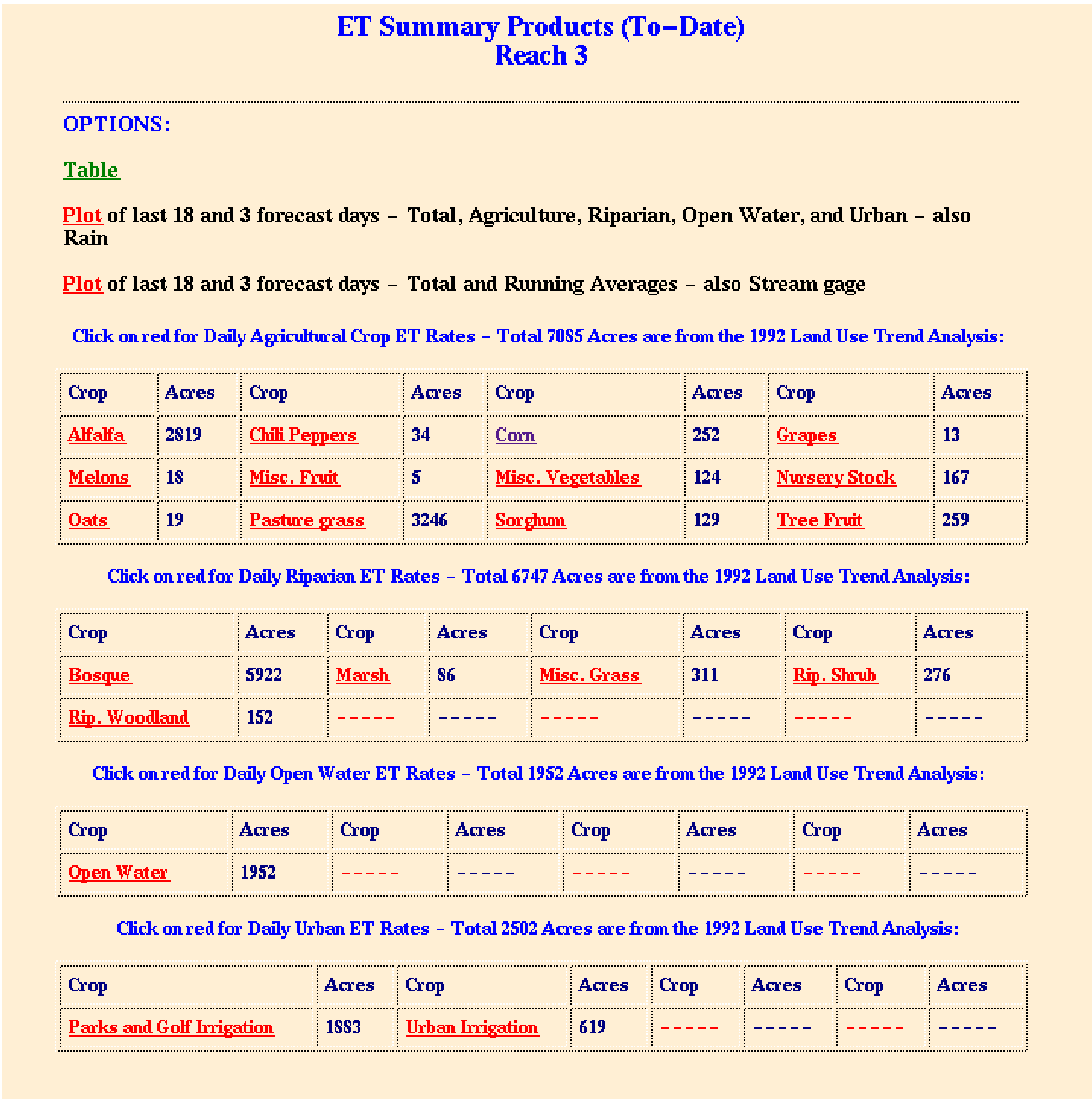
Figure 5: Grid Cell Detail Summary Example



ET Summary Products (To-Date)
Reach 3

OPTIONS:

Table

Plot of last 18 and 3 forecast days – Total, Agriculture, Riparian, Open Water, and Urban – also Rain

Plot of last 18 and 3 forecast days – Total and Running Averages – also Stream gage

Click on red for Daily Agricultural Crop ET Rates – Total 7085 Acres are from the 1992 Land Use Trend Analysis:

Crop	Acres	Crop	Acres	Crop	Acres	Crop	Acres
Alfalfa	2819	Chili Peppers	34	Corn	252	Grapes	13
Melons	18	Misc. Fruit	5	Misc. Vegetables	124	Nursery Stock	167
Oats	19	Pasture grass	3246	Sorghum	129	Tree Fruit	259

Click on red for Daily Riparian ET Rates – Total 6747 Acres are from the 1992 Land Use Trend Analysis:

Crop	Acres	Crop	Acres	Crop	Acres	Crop	Acres
Bosque	5922	Marsh	86	Misc. Grass	311	Rip. Shrub	276
Rip. Woodland	152	-----	-----	-----	-----	-----	-----

Click on red for Daily Open Water ET Rates – Total 1952 Acres are from the 1992 Land Use Trend Analysis:

Crop	Acres	Crop	Acres	Crop	Acres	Crop	Acres
Open Water	1952	-----	-----	-----	-----	-----	-----

Click on red for Daily Urban ET Rates – Total 2502 Acres are from the 1992 Land Use Trend Analysis:

Crop	Acres	Crop	Acres	Crop	Acres	Crop	Acres
Parks and Golf Irrigation	1883	Urban Irrigation	619	-----	-----	-----	-----

Figure 6: ET Summary Products Menu Example

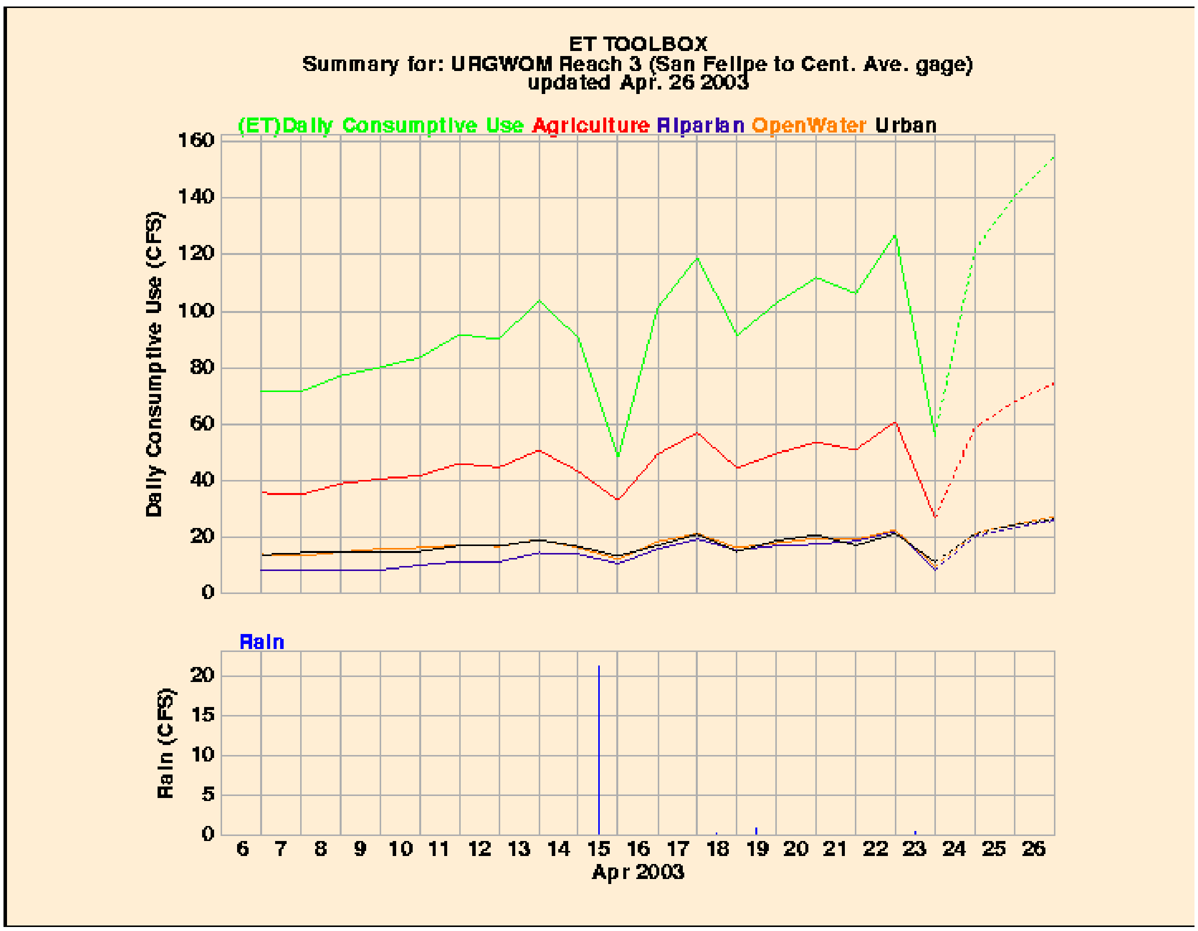


Figure 7: Reach 3 Daily Consumptive Use And Rainfall Example

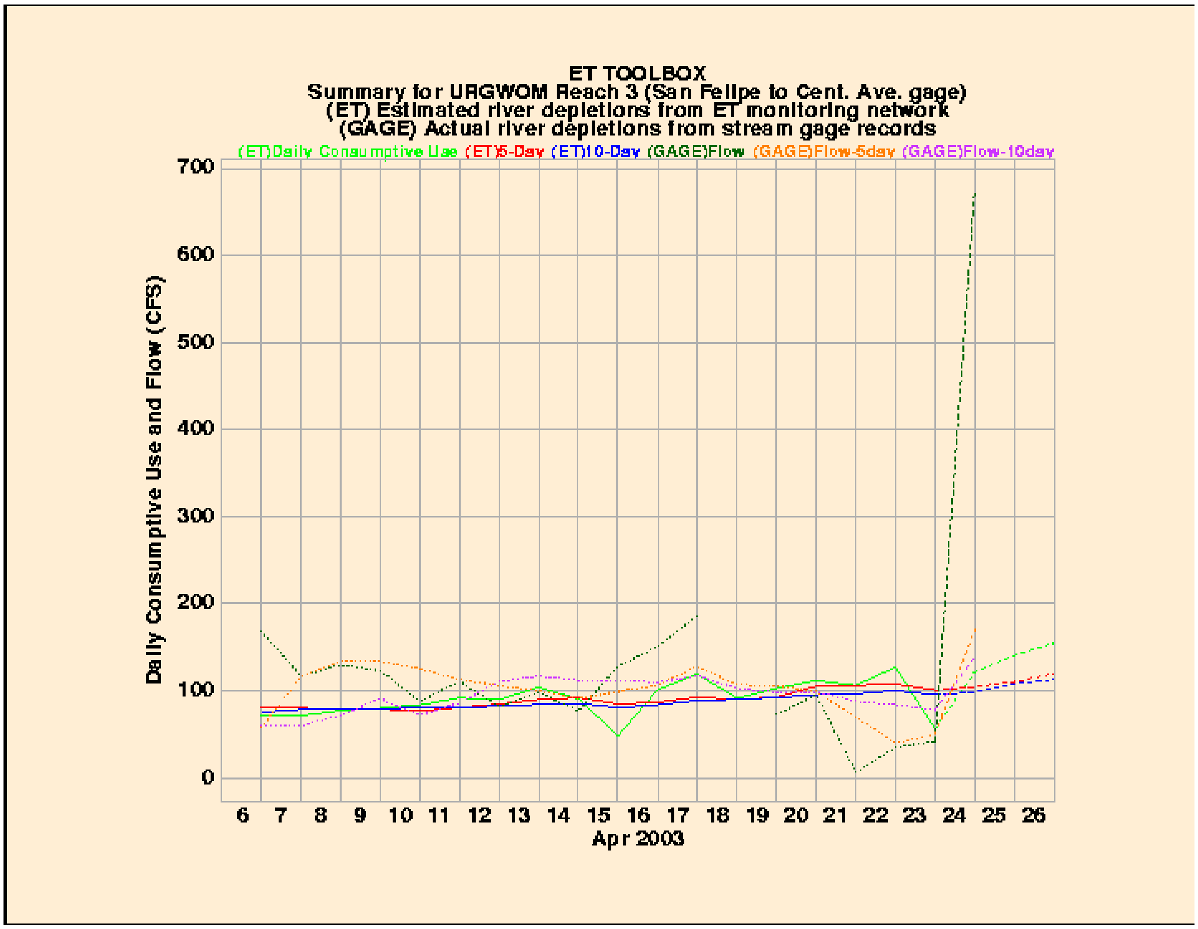


Figure 8: Reach 3 Daily Consumptive Use With Stream Flow And Running Averages Example

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Apr 24, 03 14:42 **REA3.Alfalfa.txt** Page 1/1

URGWOM Reach 3 (San Felipe to Cent. Ave. gage)

Daily ET Rates for Alfalfa Today is: Apr. 24, 2003

Vegetation Classification: LUTA 1992/93
Number of 4x4 km cells = 41 Number with Alfalfa = 20
Weather station(s) used:
1) ANGN Angostura, NM − MRGCD
2) CFMN Candelaria Farms Station − MRGCD
3) CFMN Candelaria Farms Station − MRGCD
Reference (Ref.) ET is averaged from above weather station(s)
Crop Coef. is averaged from above weather station(s)
Crop ET = Ref. ET x Crop Coef.
Total Water Use = Sum of cell water use
NEXRAD Rain = Sum of (cell rain x cell crop acres/12)
URGWOM Water Use = Total Water Use − NEXRAD Rain

Acres: 2819 Plant Date: Jan. 1 Termination Date: Oct. 20

Month Day (2003)	Ref. ET (IN)	Crop Coef.	Crop ET (IN)	Total Water Use (AC−FT)	NEXRAD Rain (AC−FT)	URGWOM Water Use (AC−FT)
Jan. 1	0.10	0.41	0.04	9.41	0.00	9.41
Jan. 2	0.09	0.41	0.04	8.01	0.00	8.01
Jan. 3	0.10	0.41	0.04	9.41	0.00	9.41
Jan. 4	0.11	0.41	0.05	9.41	0.00	9.41
Jan. 5	0.10	0.41	0.04	9.41	0.00	9.41
Jan. 6	0.12	0.41	0.05	10.79	0.00	10.79
Jan. 7	0.09	0.41	0.04	9.41	0.00	9.41
Jan. 8	0.09	0.41	0.04	9.41	0.00	9.41
Jan. 9	0.06	0.41	0.03	6.10	0.00	6.10
Jan. 10	0.08	0.41	0.03	8.43	0.00	8.43
Jan. 11	0.05	0.41	0.02	4.69	0.00	4.69
Jan. 12	0.11	0.41	0.04	9.41	0.00	9.41
Jan. 13	0.11	0.41	0.05	10.36	0.00	10.36
Jan. 14	0.10	0.41	0.04	9.41	0.00	9.41
Jan. 15	0.13	0.41	0.05	11.74	0.00	11.74
Jan. 16	0.12	0.41	0.05	10.79	0.00	10.79
Jan. 17	0.12	0.41	0.05	10.79	0.00	10.79
Jan. 18	0.11	0.41	0.05	10.79	0.00	10.79
Jan. 19	0.12	0.41	0.05	11.74	0.00	11.74
Jan. 20	0.12	0.41	0.05	10.79	0.00	10.79
Jan. 21	0.12	0.41	0.05	10.79	0.00	10.79
Jan. 22	0.13	0.41	0.05	11.74	0.00	11.74
Jan. 23	0.12	0.41	0.05	11.74	0.00	11.74
Jan. 24	0.11	0.41	0.04	10.79	0.00	10.79
Jan. 25	0.11	0.42	0.05	11.74	0.00	11.74
Jan. 26	0.12	0.42	0.05	11.74	0.00	11.74
Jan. 27	0.13	0.42	0.05	13.14	0.00	13.14
Jan. 28	0.15	0.42	0.06	15.49	0.00	15.49
Jan. 29	0.13	0.42	0.05	11.74	0.00	11.74
Jan. 30	0.15	0.42	0.06	15.49	0.00	15.49
Jan. 31	0.15	0.43	0.06	15.49	0.00	15.49
Jan. Totals	3.46		1.43	330.19	0.00	330.19
Feb. 1	0.12	0.43	0.05	11.74	0.00	11.74
Feb. 2	0.19	0.43	0.08	20.18	0.00	20.18
Feb. 3	0.10	0.43	0.04	10.79	0.00	10.79
Feb. 4	0.12	0.43	0.05	11.74	0.00	11.74
Feb. 5	0.12	0.43	0.05	12.69	0.00	12.69
Feb. 6	0.12	0.43	0.05	13.14	0.00	13.14
Feb. 7	0.09	0.43	0.04	9.41	0.00	9.41
Feb. 8	0.06	0.43	0.03	7.03	0.44	6.59
Feb. 9	0.11	0.43	0.05	12.19	0.00	12.19
Feb. 10	0.12	0.43	0.05	13.14	0.00	13.14
Feb. 11	0.11	0.43	0.05	10.79	0.00	10.79
Feb. 12	0.13	0.43	0.06	14.09	0.00	14.09
Feb. 13	0.07	0.44	0.03	7.03	52.90	−45.87
Feb. 14	0.07	0.44	0.03	8.43	4.86	3.57
Feb. 15	0.10	0.45	0.04	9.41	0.00	9.41
Feb. 16	0.10	0.45	0.04	9.41	0.00	9.41
Feb. 17	0.15	0.45	0.07	16.44	0.00	16.44
Feb. 18	0.05	0.45	0.02	5.62	0.77	4.85
Feb. 19	0.13	0.45	0.06	14.09	0.00	14.09
Feb. 20	0.02	0.45	0.01	2.34	62.26	−59.92
Feb. 21	0.16	0.45	0.07	17.85	0.00	17.85
Feb. 22	0.20	0.45	0.09	21.13	0.00	21.13
Feb. 23	0.16	0.45	0.07	17.85	0.00	17.85
Feb. 24	0.07	0.45	0.03	7.03	7.43	−0.40
Feb. 25	0.13	0.45	0.06	12.69	15.23	−2.54
Feb. 26	0.07	0.45	0.03	8.43	24.14	−15.71
Feb. 27	0.11	0.46	0.05	10.36	0.01	10.35
Feb. 28	0.08	0.46	0.04	8.43	0.76	7.67
Feb. Totals	3.08		1.36	323.47	168.80	154.67
Total To−Date	17.71		9.14	2151.61	530.11	1621.50

Thursday April 24, 2003 1/1

Figure 9: Daily ET Rates

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Jun 19, 03 11:30 **BELS.JRLN.100.288.txt** Page 1/2

Jarales − So. of Belen, NM − MRGCD
ESTIMATED CROP WATER USE − JUNE 19, 2003

CROP	START DATE	DAILY CROP WATER USE−(IN) PENMAN ET − JUNE 15	16	17	18	FORECAST PENMAN ET JUNE 19	JUNE 20	JUNE 21	TERM DATE	SUM ET	7 DAY USE	14 DAY USE
Alfalfa	101	0.44	0.37	0.32	0.21	0.54	0.52	0.46	1020	25.9	2.5	5.0
PastGrass	315	0.25	0.21	0.18	0.12	0.31	0.29	0.26	1020	17.4	1.5	2.9
Sorghum	517	0.24	0.20	0.18	0.12	0.31	0.30	0.27	1220	4.1	1.4	2.5
Wheat	410	0.15	0.12	0.10	0.07	0.18	0.17	0.15	810	5.0	0.8	1.7
Corn	429	0.31	0.26	0.23	0.15	0.39	0.38	0.33	1120	7.6	1.8	3.3
Chili Pep	429	0.31	0.26	0.23	0.15	0.39	0.38	0.33	1020	7.6	1.8	3.3
Grapes	401	0.16	0.13	0.12	0.08	0.20	0.19	0.17	1020	3.9	0.9	1.7
Urban Irr	315	0.25	0.21	0.18	0.12	0.31	0.29	0.26	1020	17.4	1.5	2.9
Park/Golf	315	0.25	0.21	0.18	0.12	0.31	0.29	0.26	1020	17.4	1.5	2.9
Rip. Wood	405	0.39	0.32	0.28	0.18	0.47	0.45	0.40	1121	16.6	2.2	4.5
Salt Cedar	405	0.32	0.26	0.23	0.15	0.39	0.38	0.34	1121	9.8	1.8	3.5
Rip. Shrub	405	0.39	0.32	0.28	0.18	0.47	0.45	0.40	1121	16.6	2.2	4.5
Marsh	101	0.45	0.37	0.32	0.21	0.54	0.52	0.46	1231	33.1	2.6	5.1
Open Water	101	0.35	0.28	0.25	0.16	0.42	0.40	0.36	1231	28.0	2.0	4.0
Misc Grass	315	0.29	0.24	0.21	0.14	0.35	0.34	0.30	1020	20.0	1.7	3.3
Melons	401	0.39	0.32	0.28	0.18	0.47	0.45	0.40	901	16.2	2.2	4.5
Tree Fruit	101	0.34	0.28	0.24	0.15	0.40	0.39	0.34	1231	24.4	1.9	3.8
Nursery St	101	0.34	0.28	0.24	0.15	0.40	0.39	0.34	1231	24.4	1.9	3.8
Oats	410	0.46	0.38	0.33	0.21	0.55	0.53	0.47	810	12.8	2.6	5.1
Misc Fruit	101	0.34	0.28	0.24	0.15	0.40	0.39	0.34	1231	24.4	1.9	3.8
Misc Vegs	429	0.31	0.26	0.23	0.15	0.39	0.38	0.33	1020	7.6	1.8	3.3
Bosque	405	0.39	0.32	0.28	0.18	0.47	0.45	0.40	1121	16.6	2.2	4.5
Cottonwood	405	0.20	0.17	0.15	0.10	0.25	0.24	0.21	1121	8.1	1.2	2.3

NEXRAD HRS AVAIL	24	24	24	24	QPF	QPF valid until:
TOTAL RAIN	0.05	0.00	0.02	0.01	0.00	5am MST JUN 20
EFFECTIVE RAIN	0.05	0.00	0.02	0.01	0.00	

NEXRAD MONTHLY TOTAL RAIN:	
JANUARY	0.00
FEBRUARY	0.25
MARCH	0.17
APRIL	0.04
MAY	0.00

Thursday June 19, 2003 1/2

Figure 10: ET Chart Example

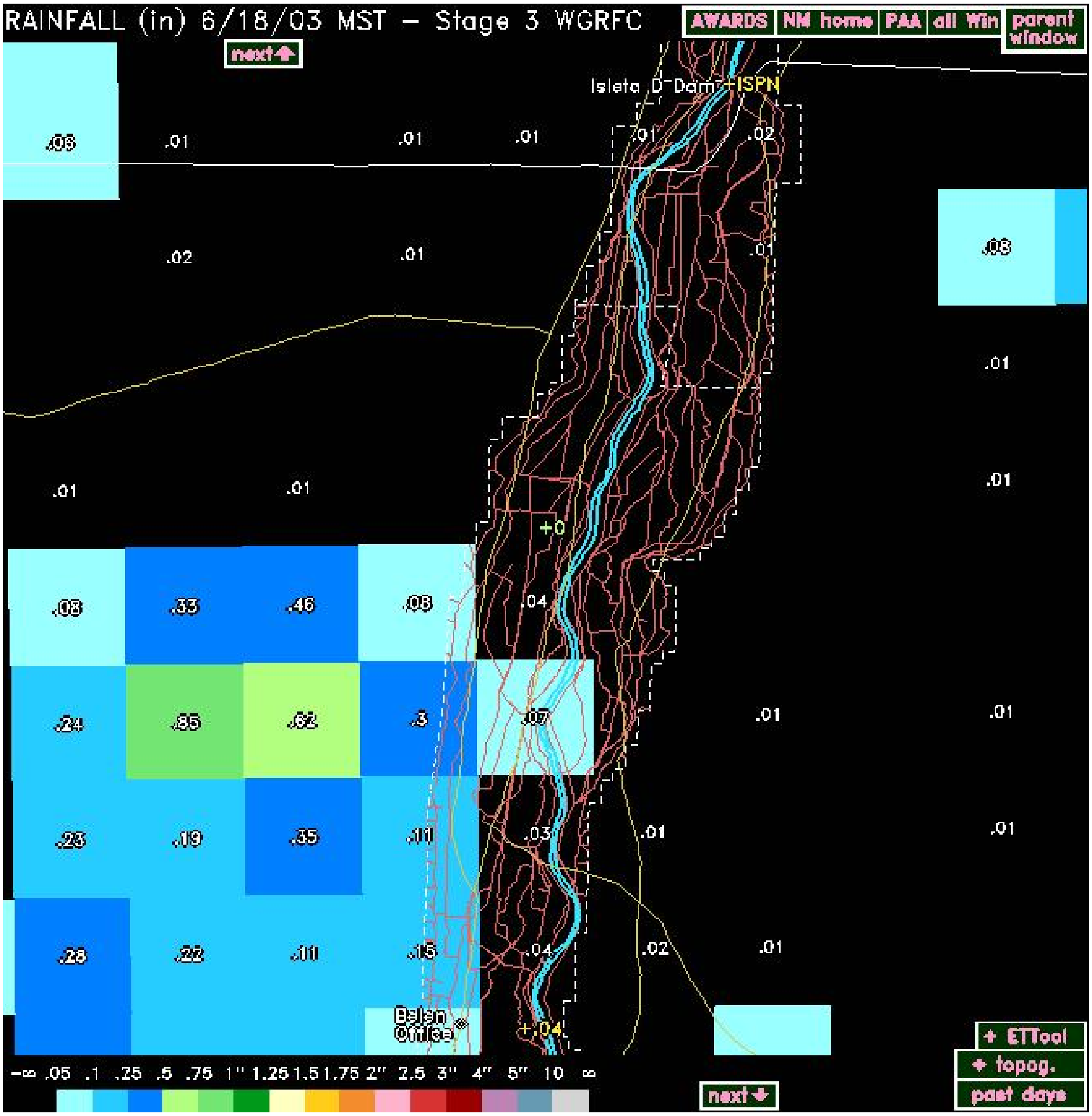

Figure 11: Belen North AWARDS Example

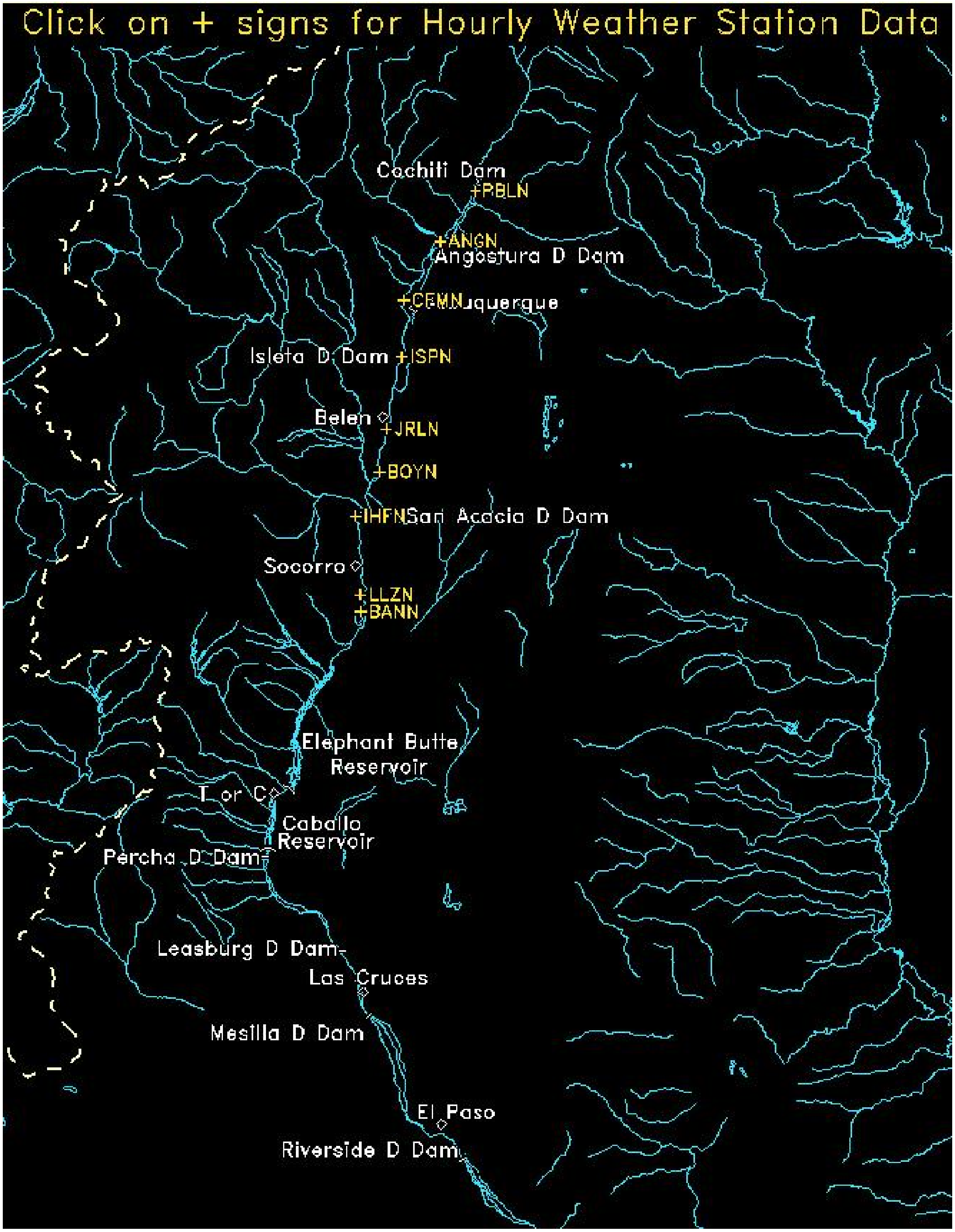

Figure 12: MRGCD Weather Station Network

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Jun 05, 03 11:12 **CFMN503.hrs.txt** Page 1/1

Candelaria Farms − MRGCD CFMN

Hourly Weather Data for Last 24−Hours − 2003

Month	Day	Time (MST)	Temp. (F)	Wind (Mi/Hr)	Wind Dir. (Deg)	Rel. Hum. (%)	Rain (in)	Solar Radiation (Mj/Sq m)	Soil Temp. (F)
June	05	10AM	75.2	0.5	166	45	0.00	2.74	69.0
June	05	9AM	71.2	0.7	208	52	0.00	1.97	69.0
June	05	8AM	67.8	0.9	240	62	0.00	1.05	69.1
June	05	7AM	65.0	3.8	240	64	0.00	0.84	69.3
June	05	6AM	60.7	2.5	245	71	0.00	0.25	69.6
June	05	5AM	61.9	2.6	259	67	0.00	0.01	69.9
June	05	4AM	62.1	1.4	289	64	0.00	0.00	70.2
June	05	3AM	66.5	4.8	116	52	0.00	0.00	70.5
June	05	2AM	67.3	5.7	133	53	0.00	0.00	70.8
June	05	1AM	68.6	6.9	103	51	0.00	0.00	71.0
June	04	12PM	70.2	5.1	123	48	0.00	0.01	71.4
June	04	11PM	70.9	9.1	105	48	0.00	0.01	71.7
June	04	10PM	68.3	3.2	186	39	0.00	0.01	72.1
June	04	9PM	67.5	1.2	217	36	0.00	0.01	72.5
June	04	8PM	70.4	0.3	226	35	0.00	0.01	72.7
June	04	7PM	78.9	1.3	216	21	0.00	0.16	72.9
June	04	6PM	83.6	6.6	188	17	0.00	0.82	72.9
June	04	5PM	83.9	11.2	248	13	0.00	0.37	72.7
June	04	4PM	86.9	6.8	284	16	0.00	1.60	72.3
June	04	3PM	86.1	5.6	246	16	0.00	1.50	71.4
June	04	2PM	86.9	6.2	273	18	0.00	2.77	70.2
June	04	1PM	86.0	4.2	209	23	0.00	3.44	69.1
June	04	12AM	83.2	2.6	163	29	0.00	3.41	68.2
June	04	11AM	81.0	0.4	187	32	0.00	3.24	67.5

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Figure 13: MRGCD Hourly Weather Data Example

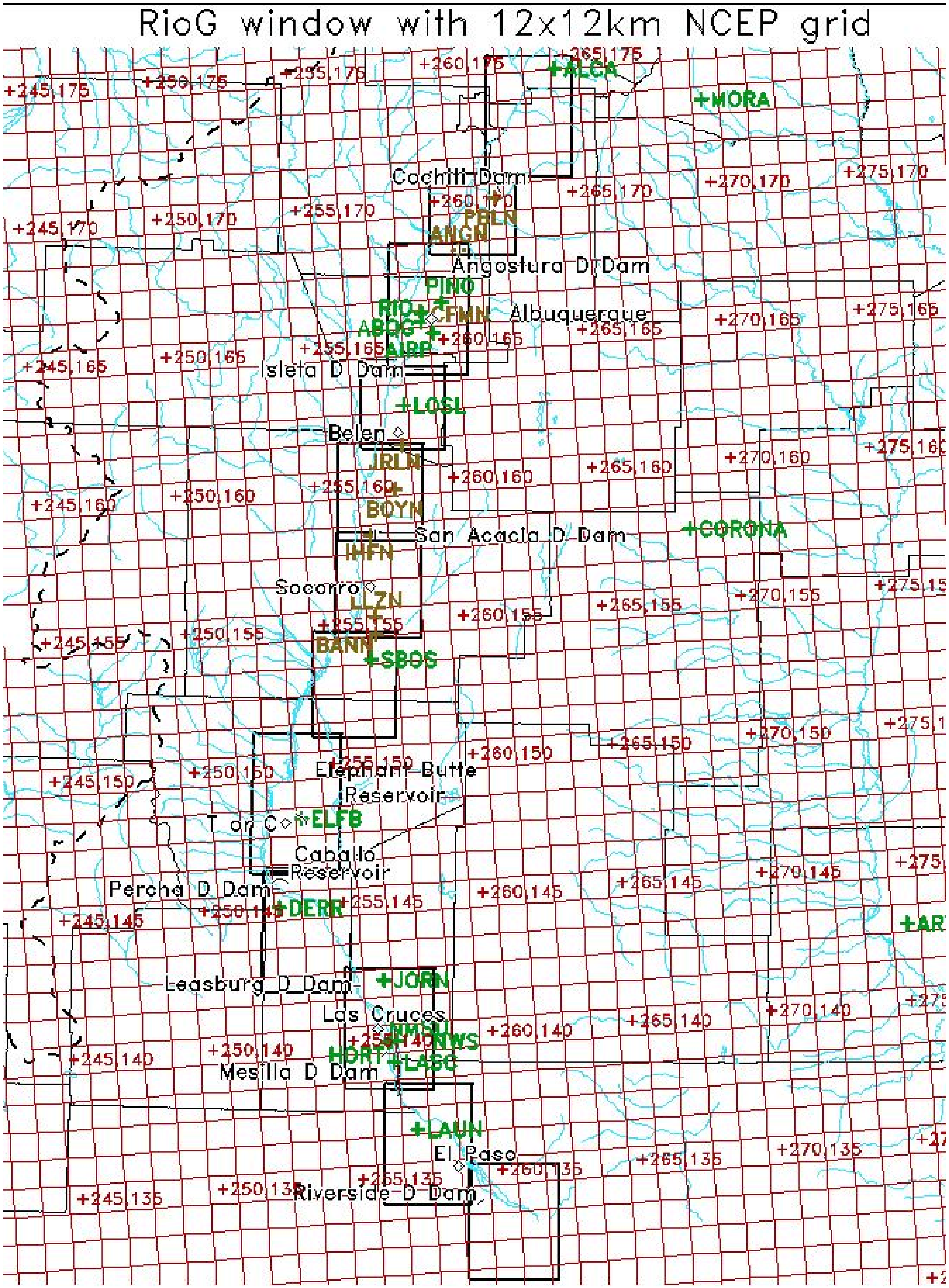

Figure 14: 12-km NCEP Grid (Eta Cell) For The Middle Rio Grande

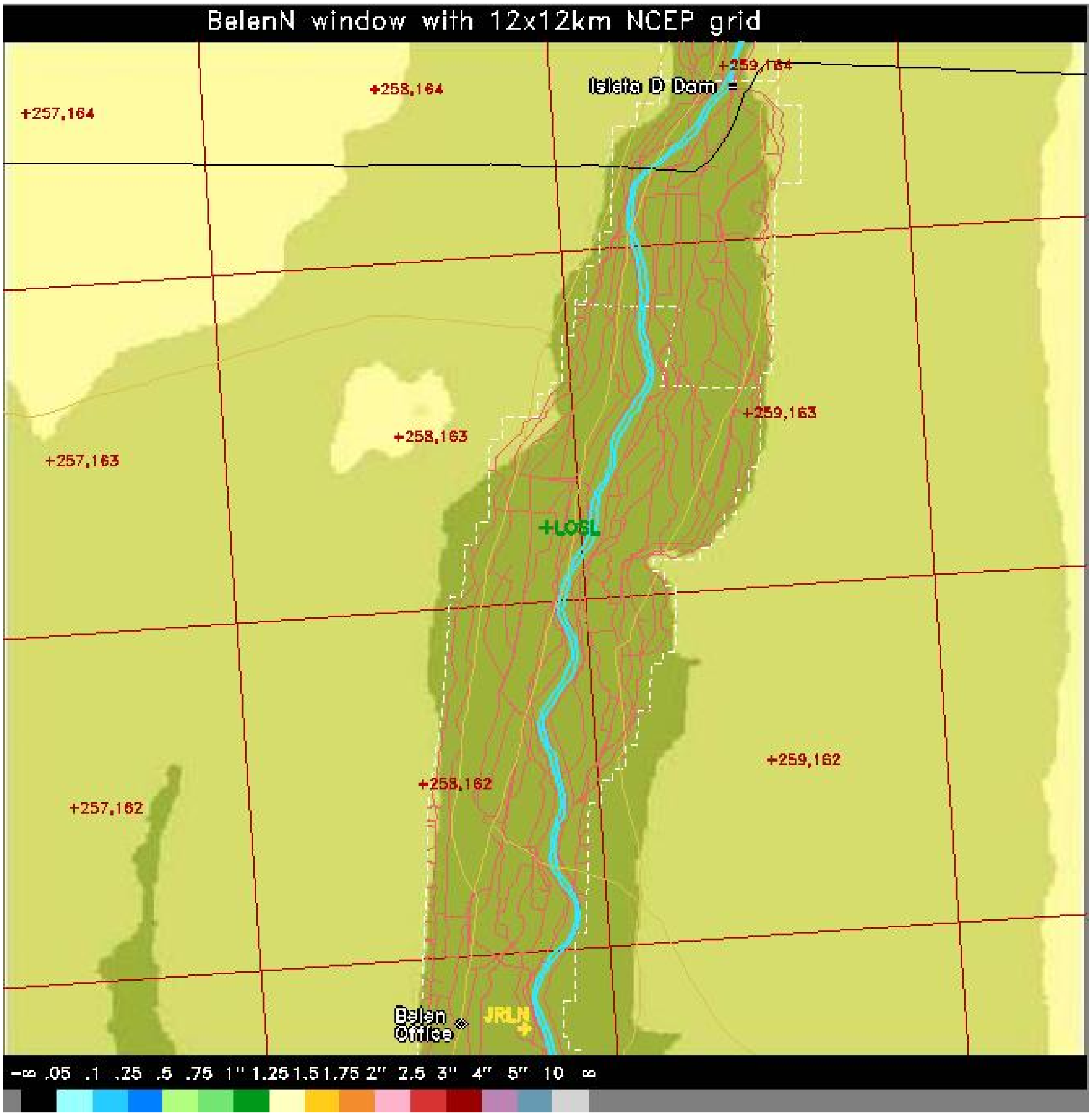

Figure 15: 12-km NCEP Grid For Belen North

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```
      subroutine etpbyts
c
c Penman's equation for reference et (ETr), referenced to grass
c  This is the modified Penman equation as modified by Dr. Ted Sammis
c  at the New Mexico State University, as provided by Salim Bawazir
c  on March 16, 2000.
c
c List of Input Values
c
c Name      Value  Units              Description
c  elev     Input  m                    elevation
c  tmax     Input  deg.C                maximum temperature
c  tmin     Input  deg.C                minimum temperature
c  rhmax    Input  %                    maximum relative humidity
c  rhmin    Input  %                    minimum relative humidity
c  wr_value Input  m/sec                wind speed
c  sr_value Input  megajoules/m^2.day   solar radiation
c
      integer errors2
      include 'refet.common'
c
c Initalize
c
c Reflection coefficient, 0.07+0.053*LAI
      albedo=.21
c Specific heat of air (cal/deg.C/cm^3)
      cp=.242
c Long wave radiation (cal/cm^2/day)
      rl=-64.
c
c Perform calculations
c
c Find maximum saturated vapor pressure (mb)
      svpma = 6.108*exp((17.27*tmax)/(tmax+237.3))
c Find minimum saturated vapor pressure (mb)
      svpmi = 6.108*exp((17.27*tmin)/(tmin+237.3))
c Find saturated vapor pressure at mean temperature (mb)
      vps1 = (svpmi+svpma)/2.0
c Find actual vapor pressure at mean temperature (mb)
      vpa1 = ((svpma*rhmin/100.) + (svpmi*rhmax/100.))/2.
c Find difference between saturated vapor pressure at mean temperature
c  and actual vapor pressure at mean temperature (mb)
      vpdiff = vps1-vpa1
c Find average temperature
      tavg=(tmax+tmin)/2.
c Find slope of the saturated vapor pressure curve (mb/deg C)
      delta = 33.8639*(0.05904*(0.00739*tavg+0.8072)**7 - 0.0000342)
c Find latent heat of vaporization (cal/g)
      hl = 595.0-(0.51*tavg)
c Find pressure when elevation is in meters (mb)
      pr = 1013.0-(0.1055*elev)
c Find psychrometric constant
      gamma = (cp*pr)/(0.622*hl)
c Convert average wind speed from meters/second to km/hr
      windkm = wr_value*86400.*.001/24.
c Find wind speed at 2 meters - assumes instrument is at 3.75 meters
c  (km/day)
      wind2m = (windkm*24.)*((2/3.75)**.2)
c Find wind function (km/day)
      windf = 15.36*(1.0+(0.0062*wind2m))
c Find net solar radiation where sr_value is in mj/m^2/day
c  (cal/cm^2/day
      rn=(.95*(1.0-albedo)*sr_value/0.041868)+rl
c Find reference et (cal/cm**2/day)
```

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```
      eto = ((delta/(delta+gamma))*rn)+
     2 ((gamma/(delta+gamma))*windf*vpdiff)
c Find reference et (mm/day)
      eto = (eto/hl)*10.
c Find reference et (in/day)
      Eto = eto*.03937
      return
      end
```

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Figure 16: Penman Reference ET Equation

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Station	Crop num.	Crop name	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
LLZN	1	Alfalfa				.11	.19	.27	.30	.24	.15	.09		
LLZN	2	PastGrass				.10	.16	.22	.25	.21	.14	.08		
LLZN	3	Sorghum					.06	.14	.26	.20	.10			
LLZN	4	Wheat			.04	.12	.26	.11						
LLZN	5	Corn					.09	.13	.25	.24	.16			
LLZN	6	Chili Pep						.01	.09	.23	.18	.01		
LLZN	7	Grapes				.06	.13	.20	.21	.17	.10	.05		
LLZN	33	Misc Vegs				.05	.08	.14	.27	.26	.15	.08		

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Figure 17: Limited ET As Calculated At The Luis Lopez Station

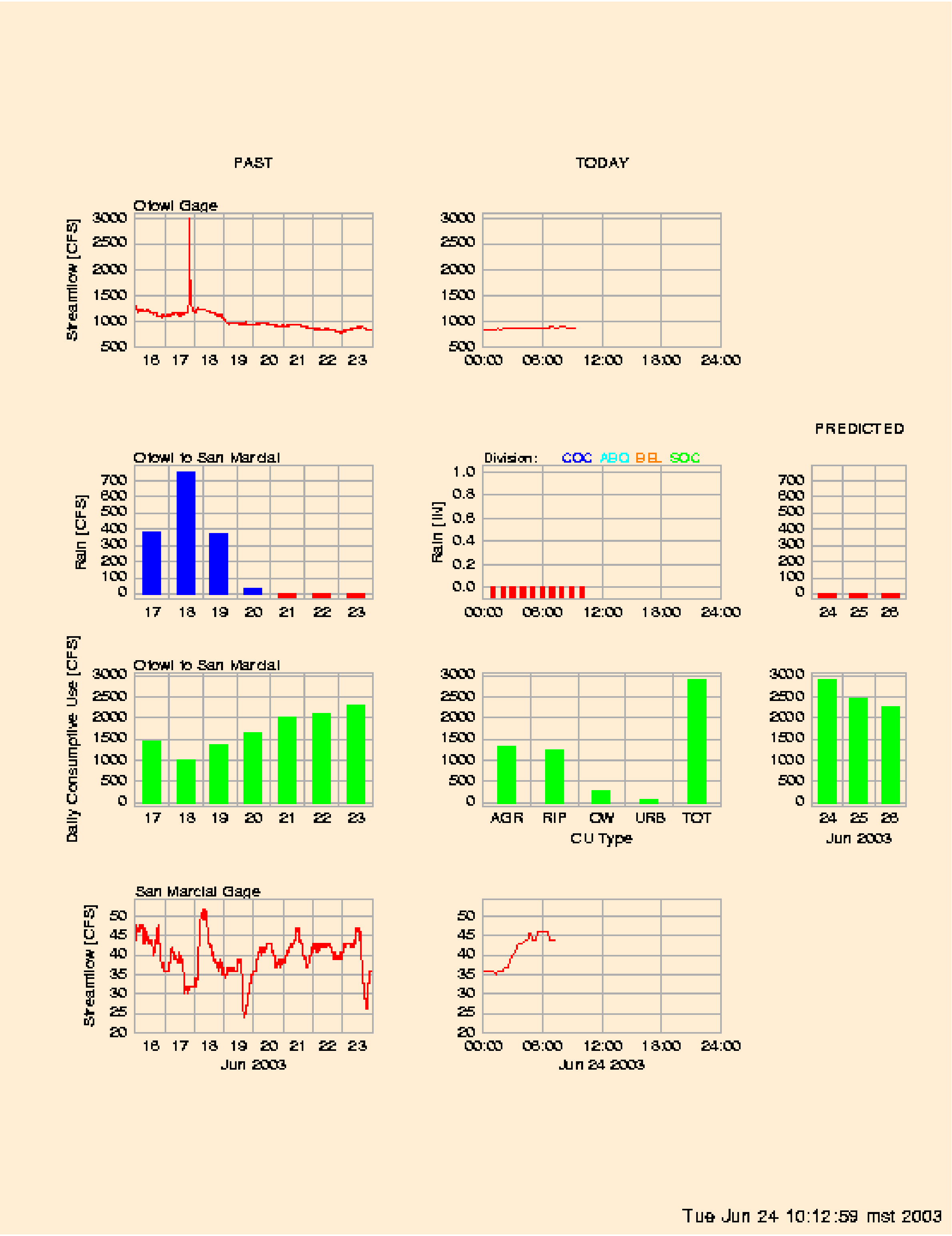


Figure 18: With Present Division Rain matrix

[030627]

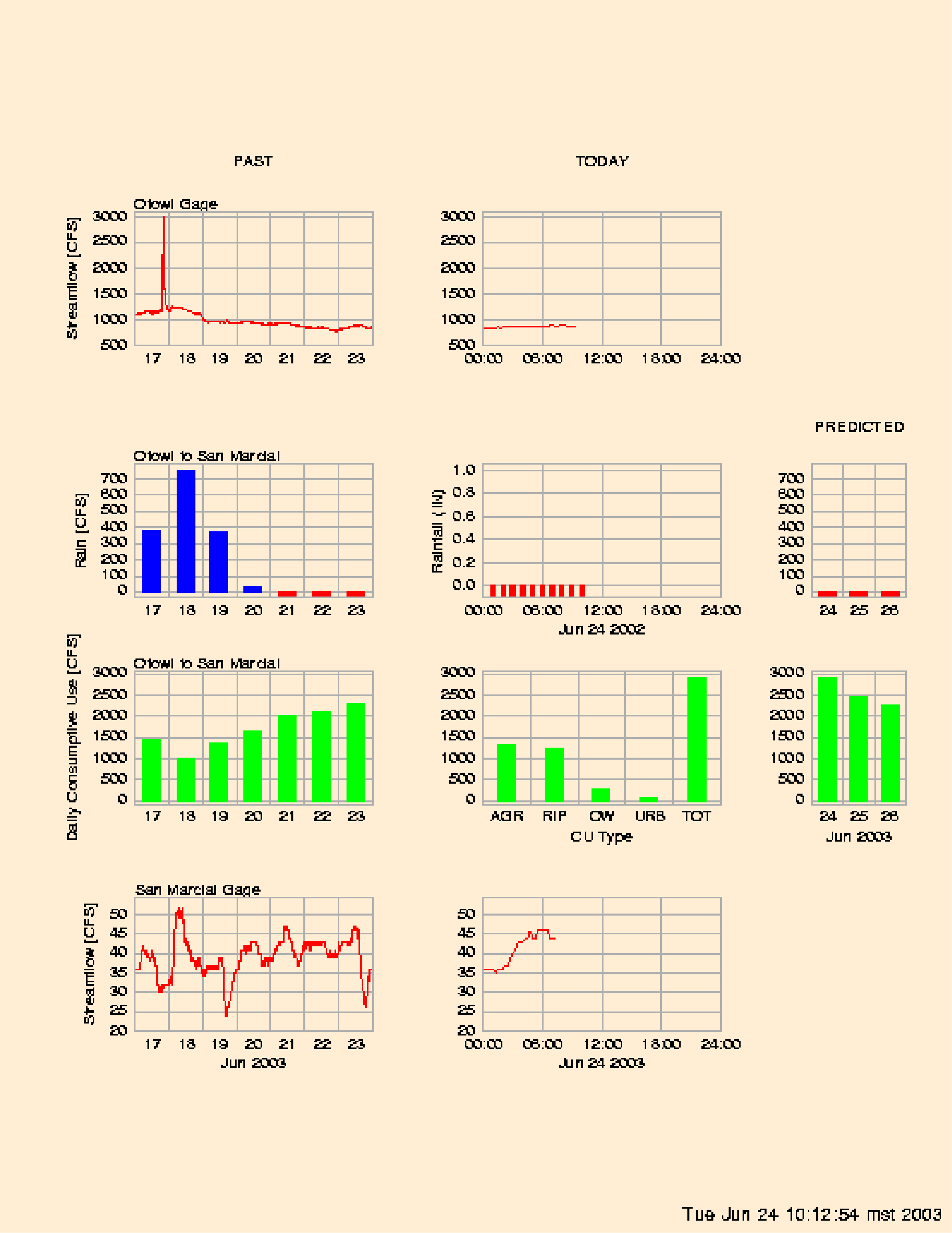
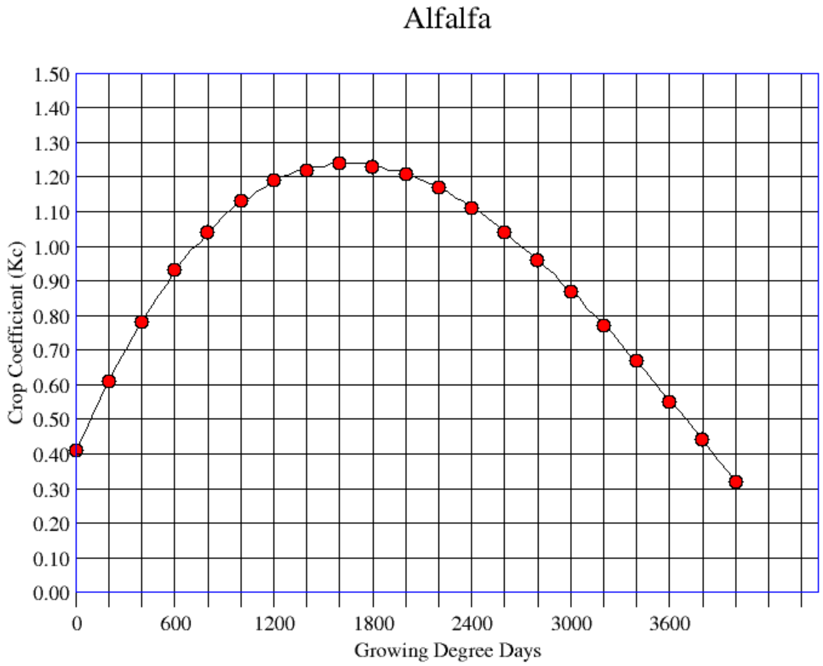


Figure 19: With Present Hourly Rain matrix

Figure 20: Alfalfa Curve

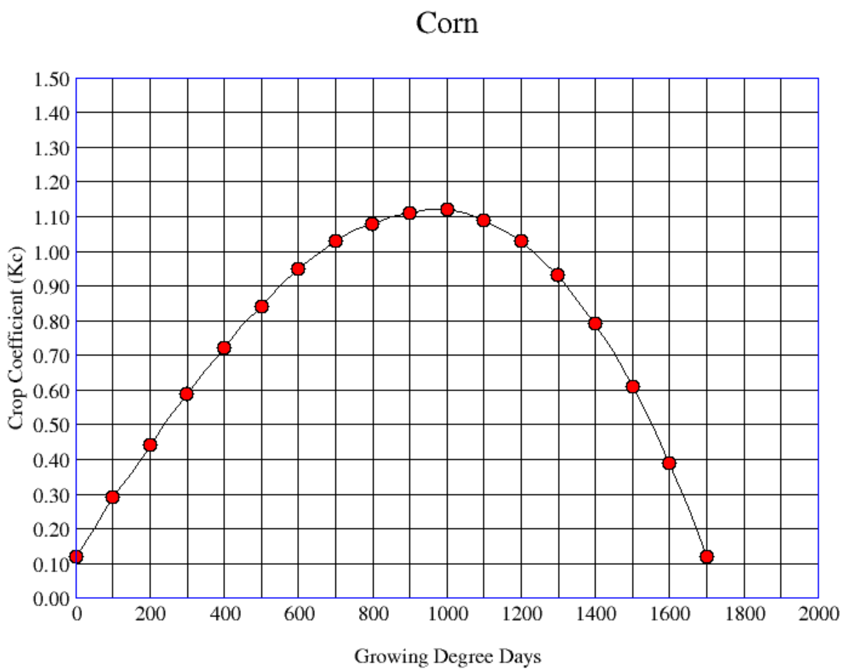



```
                Polynominal Function for Alfalfa

Kc  =    0.41E+00 +   0.111E-02(GDD) +  -0.425E-06(GDD)**2 +
                   0.356E-10(GDD)**3 +   0.000E+00(GDD)**4 +
                   0.000E+00(GDD)**5

Base Temperature (deg. C) =   5.0
```

GDD	Kc	GDD	Kc	GDD	Kc	GDD	Kc	GDD	Kc	GDD	Kc	GDD	Kc
----	----	----	----	----	----	----	----	----	----	----	----	----	----
0	0.41	600	0.93	1200	1.19	1800	1.23	2400	1.11	3000	0.87	3600	0.55
50	0.46	650	0.96	1250	1.20	1850	1.23	2450	1.10	3050	0.85	3650	0.53
100	0.51	700	0.99	1300	1.21	1900	1.22	2500	1.08	3100	0.82	3700	0.50
150	0.56	750	1.01	1350	1.22	1950	1.22	2550	1.06	3150	0.80	3750	0.47
200	0.61	800	1.04	1400	1.22	2000	1.21	2600	1.04	3200	0.77	3800	0.44
250	0.66	850	1.06	1450	1.23	2050	1.20	2650	1.02	3250	0.75	3850	0.41
300	0.70	900	1.09	1500	1.23	2100	1.19	2700	1.00	3300	0.72	3900	0.38
350	0.74	950	1.11	1550	1.24	2150	1.18	2750	0.98	3350	0.69	3950	0.35
400	0.78	1000	1.13	1600	1.24	2200	1.17	2800	0.96	3400	0.67	4000	0.32
450	0.82	1050	1.14	1650	1.24	2250	1.16	2850	0.94	3450	0.64		
500	0.86	1100	1.16	1700	1.24	2300	1.14	2900	0.92	3500	0.61		
550	0.89	1150	1.17	1750	1.24	2350	1.13	2950	0.89	3550	0.58		

Curve developed by New Mexico State University

Figure 21: Corn Curve

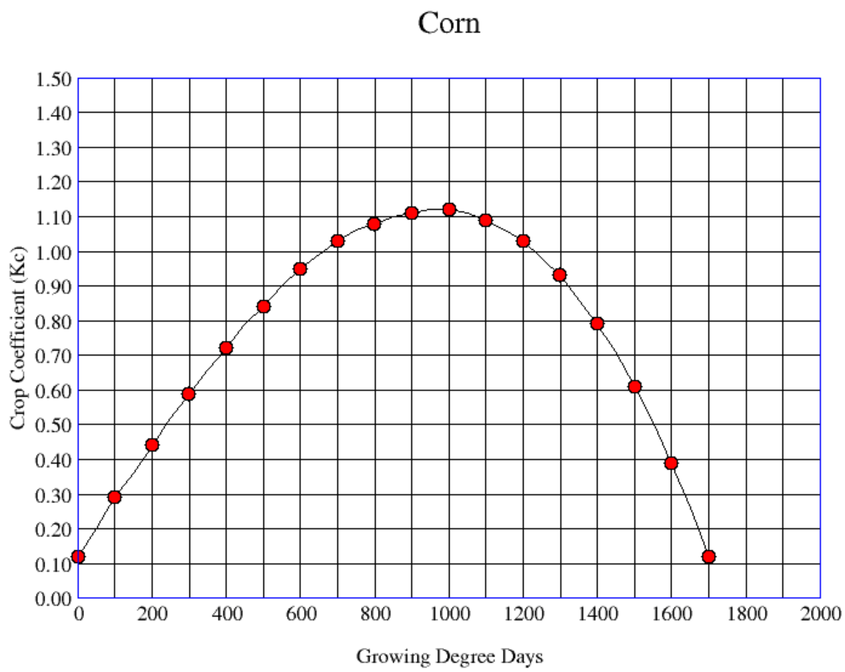



```
                Polynominal Function for Corn

Kc  =    0.12E+00 +   0.168E-02(GDD) +  -0.246E-06(GDD)**2 +
                   -0.437E-09(GDD)**3 +   0.000E+00(GDD)**4 +
                    0.000E+00(GDD)**5

Max. Cutoff Temperature (deg. C) =  30.0
Min. Cutoff Temperature (deg. C) =  10.0
Base Temperature (deg. C) =  10.0
```

GDD	Kc	GDD	Kc	GDD	Kc
0	0.12	600	0.95	1200	1.03
50	0.20	650	0.99	1250	0.98
100	0.29	700	1.03	1300	0.93
150	0.36	750	1.06	1350	0.86
200	0.44	800	1.08	1400	0.79
250	0.52	850	1.10	1450	0.71
300	0.59	900	1.11	1500	0.61
350	0.66	950	1.12	1550	0.51
400	0.72	1000	1.12	1600	0.39
450	0.79	1050	1.11	1650	0.26
500	0.84	1100	1.09	1700	0.12
550	0.90	1150	1.06		

Curve developed by New Mexico State University

Figure 22: Corn Curve

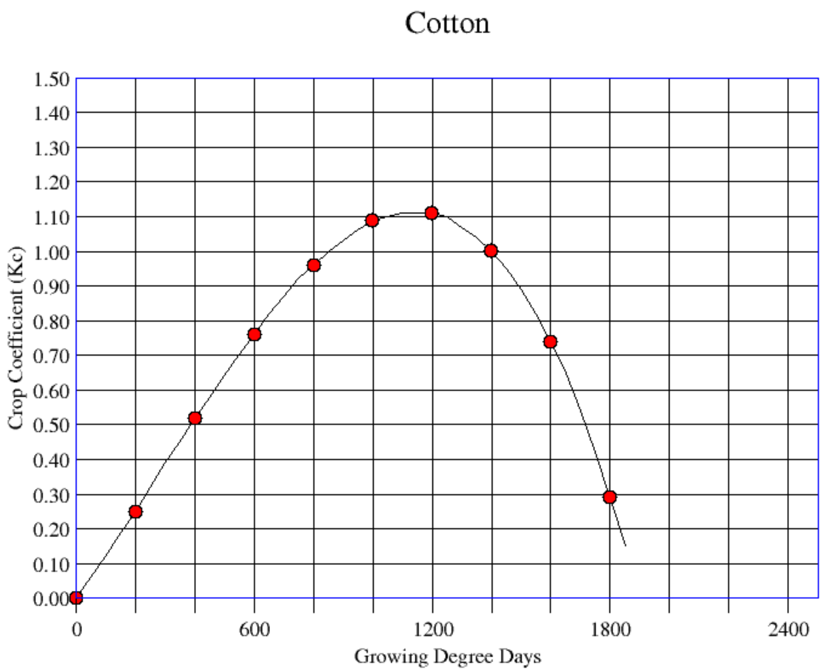



```
                Polynominal Function for Corn

Kc  =    0.12E+00 +   0.168E-02(GDD) +  -0.246E-06(GDD)**2 +
                  -0.437E-09(GDD)**3 +   0.000E+00(GDD)**4 +
                   0.000E+00(GDD)**5

Max. Cutoff Temperature (deg. C) =  30.0
Min. Cutoff Temperature (deg. C) =  10.0
Base Temperature (deg. C) =  10.0
```

GDD	Kc	GDD	Kc	GDD	Kc
0	0.12	600	0.95	1200	1.03
50	0.20	650	0.99	1250	0.98
100	0.29	700	1.03	1300	0.93
150	0.36	750	1.06	1350	0.86
200	0.44	800	1.08	1400	0.79
250	0.52	850	1.10	1450	0.71
300	0.59	900	1.11	1500	0.61
350	0.66	950	1.12	1550	0.51
400	0.72	1000	1.12	1600	0.39
450	0.79	1050	1.11	1650	0.26
500	0.84	1100	1.09	1700	0.12
550	0.90	1150	1.06		

Curve developed by New Mexico State University

Figure 23: Cotton Curve

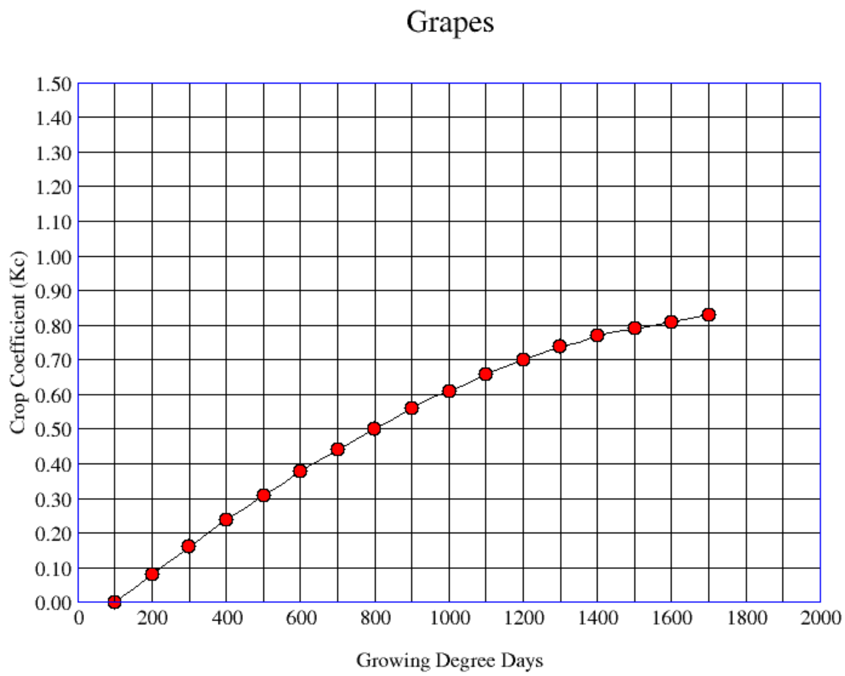



```
                Polynominal Function for Cotton

Kc  =    0.42E-03 +   0.120E-02(GDD) +   0.462E-06(GDD)**2 +
                    -0.577E-09(GDD)**3 +   0.000E+00(GDD)**4 +
                     0.000E+00(GDD)**5

Max. Cutoff Temperature (deg. C) =  30.0
Min. Cutoff Temperature (deg. C) =  12.0
Base Temperature (deg. C) =  12.0
```

GDD	Kc	GDD	Kc	GDD	Kc	GDD	Kc
----	----	----	----	----	----	----	----
0	0.00	600	0.76	1200	1.11	1800	0.29
50	0.06	650	0.82	1250	1.10	1850	0.15
100	0.12	700	0.87	1300	1.07		
150	0.19	750	0.92	1350	1.04		
200	0.25	800	0.96	1400	1.00		
250	0.32	850	1.00	1450	0.95		
300	0.39	900	1.03	1500	0.89		
350	0.45	950	1.06	1550	0.82		
400	0.52	1000	1.09	1600	0.74		
450	0.58	1050	1.10	1650	0.65		
500	0.64	1100	1.11	1700	0.54		
550	0.70	1150	1.11	1750	0.42		

Curve developed by New Mexico State University

Figure 24: Grape Curve



Polynominal Function for Grapes

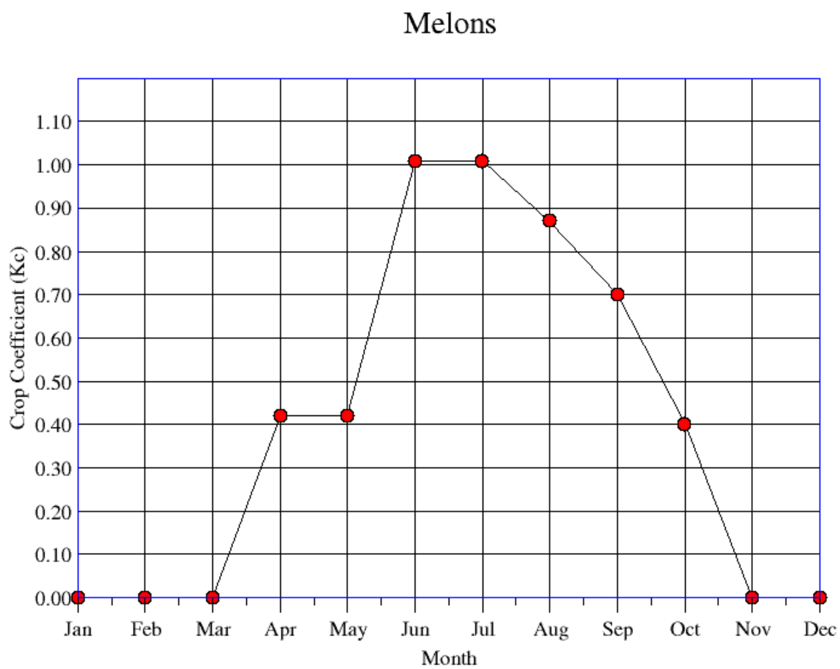
```
Kc  =   -0.91E-01 +   0.881E-03(GDD) +  -0.150E-06(GDD)**2 +
                  -0.300E-10(GDD)**3 +   0.000E+00(GDD)**4 +
                   0.000E+00(GDD)**5
```

```
Max. Cutoff Temperature (deg. C) =  30.0
Min. Cutoff Temperature (deg. C) =  10.0
Base Temperature (deg. C) =  10.0
```

GDD	Kc	GDD	Kc	GDD	Kc
150	0.04	750	0.47	1350	0.75
200	0.08	800	0.50	1400	0.77
250	0.12	850	0.53	1450	0.78
300	0.16	900	0.56	1500	0.79
350	0.20	950	0.59	1550	0.80
400	0.24	1000	0.61	1600	0.81
450	0.27	1050	0.63	1650	0.82
500	0.31	1100	0.66	1700	0.83
550	0.34	1150	0.68		
600	0.38	1200	0.70		
650	0.41	1250	0.72		
700	0.44	1300	0.74		

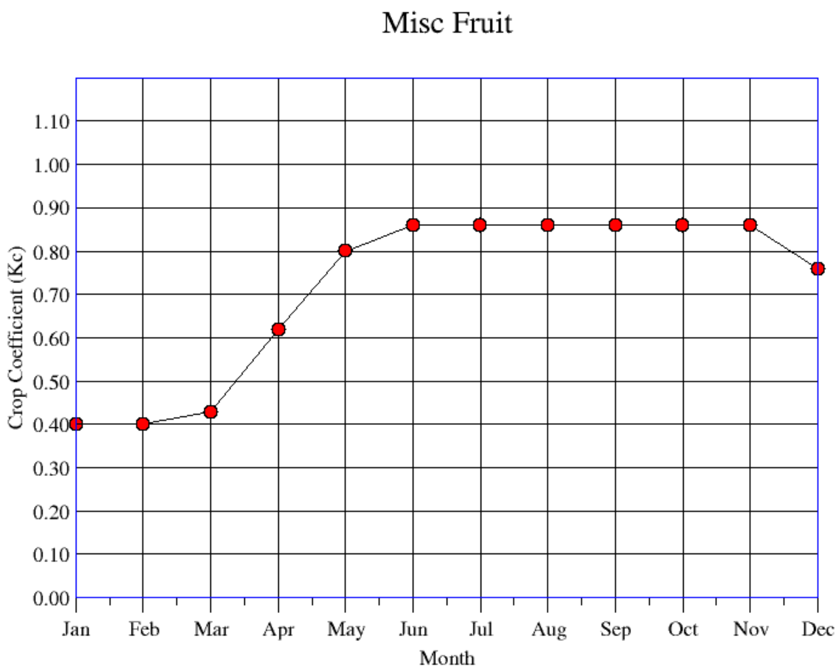
Curve developed by New Mexico State University

Figure 25: Melon Curve




```
 Monthly Coefficients for Melons

 Month     Crop Coefficient (Kc)
---------  ---------------------
January           0.00
February          0.00
March             0.00
April             0.42
May               0.42
June              1.01
July              1.01
August            0.87
September         0.70
October           0.40
November          0.00
December          0.00

Data from Jensen,M.E., (1998)
```

Figure 26: Misc. Fruit Curve

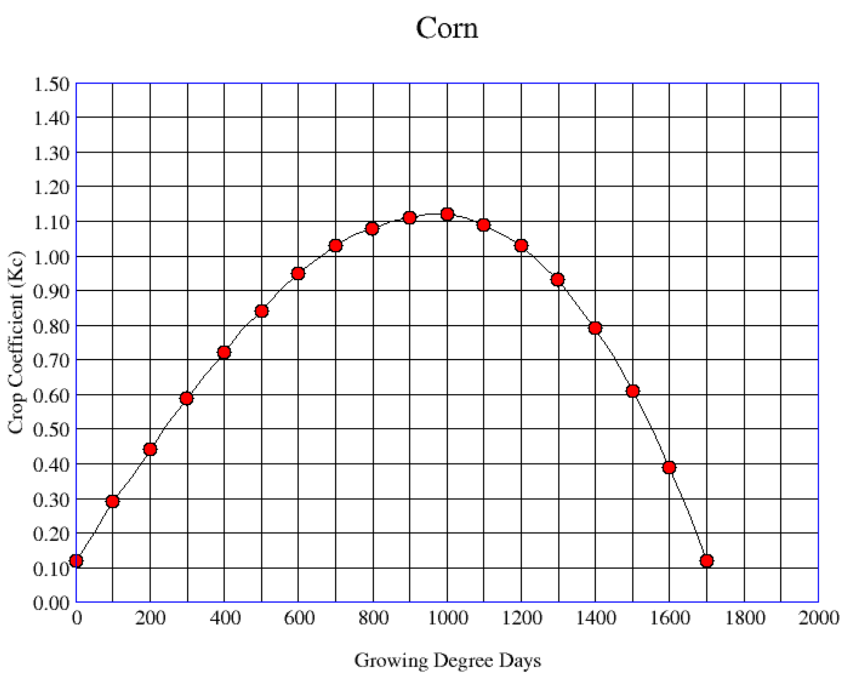


Monthly Coefficients for Misc Fruit

Month	Crop Coefficient (Kc)
January	0.40
February	0.40
March	0.43
April	0.62
May	0.80
June	0.86
July	0.86
August	0.86
September	0.86
October	0.86
November	0.86
December	0.76

Data from Jensen,M.E., (1998)

Figure 27: Corn Curve



Polynominal Function for Corn

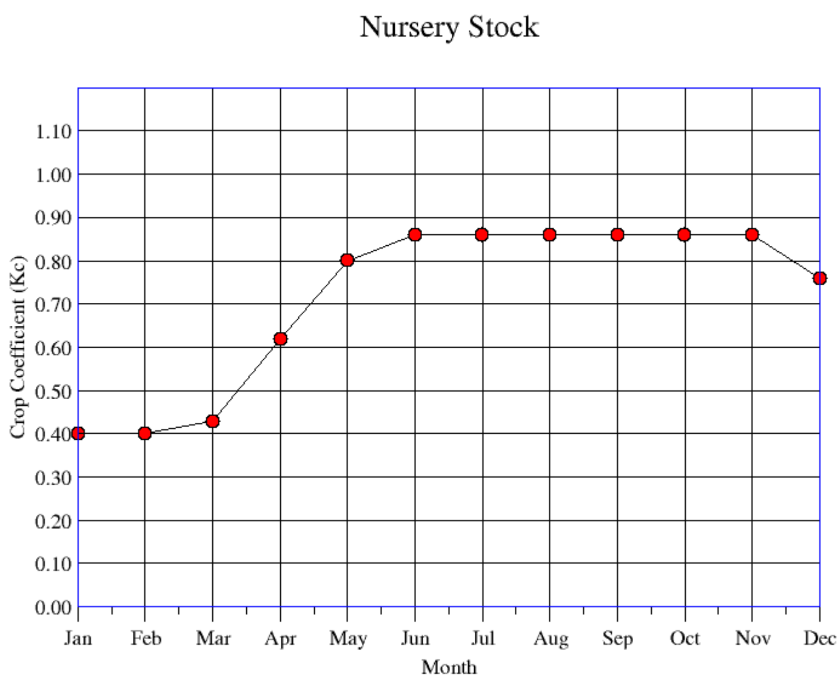
```
Kc  =    0.12E+00 +   0.168E-02(GDD) +  -0.246E-06(GDD)**2 +
                  -0.437E-09(GDD)**3 +   0.000E+00(GDD)**4 +
                   0.000E+00(GDD)**5
```

Max. Cutoff Temperature (deg. C) = 30.0
Min. Cutoff Temperature (deg. C) = 10.0
Base Temperature (deg. C) = 10.0

GDD	Kc	GDD	Kc	GDD	Kc
0	0.12	600	0.95	1200	1.03
50	0.20	650	0.99	1250	0.98
100	0.29	700	1.03	1300	0.93
150	0.36	750	1.06	1350	0.86
200	0.44	800	1.08	1400	0.79
250	0.52	850	1.10	1450	0.71
300	0.59	900	1.11	1500	0.61
350	0.66	950	1.12	1550	0.51
400	0.72	1000	1.12	1600	0.39
450	0.79	1050	1.11	1650	0.26
500	0.84	1100	1.09	1700	0.12
550	0.90	1150	1.06		

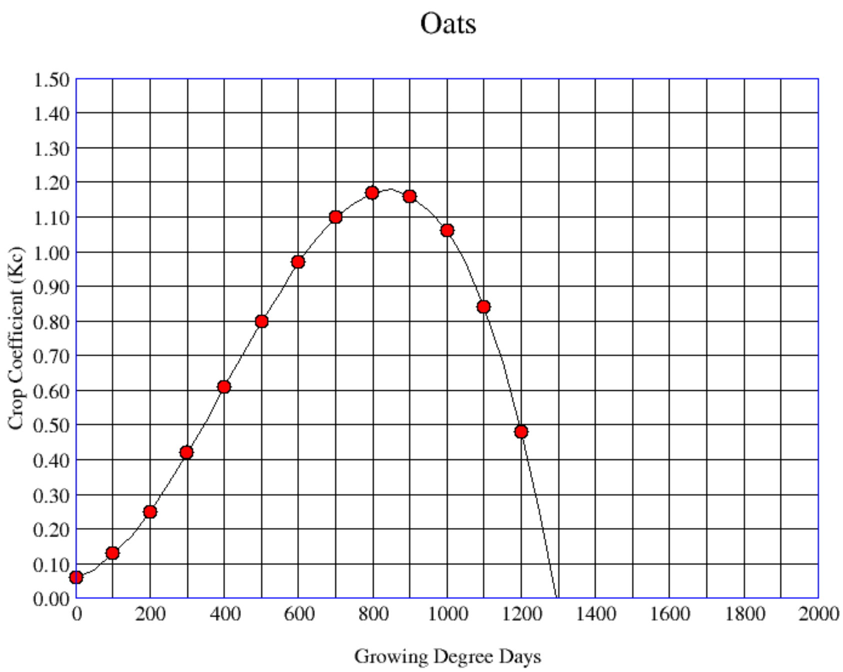
Curve developed by New Mexico State University

Figure 28: Nursery Stock Curve




```
 Monthly Coefficients for Nursery Stock

 Month     Crop Coefficient (Kc)
---------  ---------------------
January           0.40
February          0.40
March             0.43
April             0.62
May               0.80
June              0.86
July              0.86
August            0.86
September         0.86
October           0.86
November          0.86
December          0.76

Data from Jensen,M.E., (1998)
```

Figure 29: Spring Barley Curve

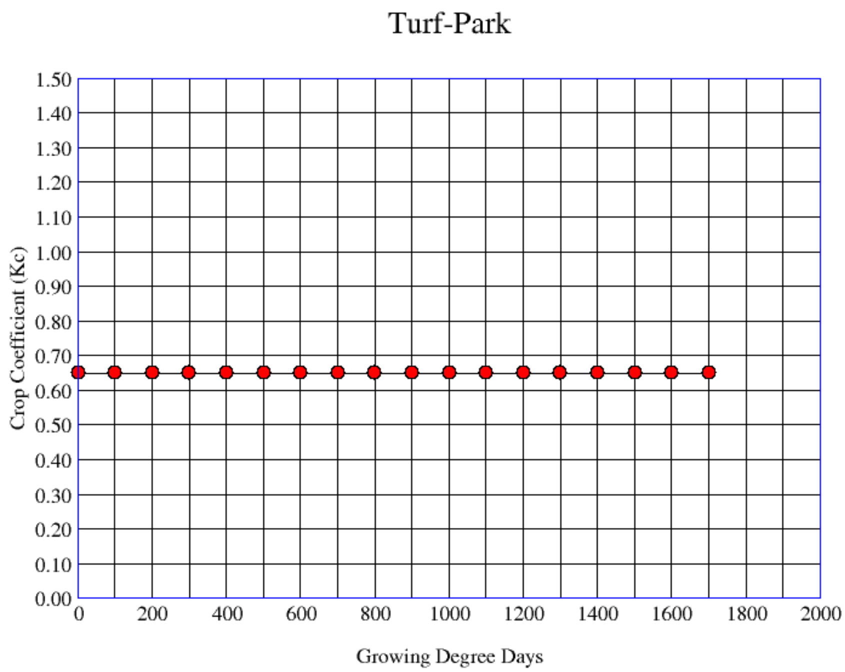



```
              Polynominal Function for Oats

Kc  =    0.57E-01 +   0.323E-03(GDD) +   0.394E-05(GDD)**2 +
                    -0.326E-08(GDD)**3 +   0.000E+00(GDD)**4 +
                     0.000E+00(GDD)**5

Max. Cutoff Temperature (deg. C) =  30.0
Min. Cutoff Temperature (deg. C) =   5.0
Base Temperature (deg. C) =   5.0
```

GDD	Kc	GDD	Kc	GDD	Kc
0	0.06	600	0.97	1200	0.48
50	0.08	650	1.04	1250	0.25
100	0.13	700	1.10		
150	0.18	750	1.14		
200	0.25	800	1.17		
250	0.33	850	1.18		
300	0.42	900	1.16		
350	0.51	950	1.12		
400	0.61	1000	1.06		
450	0.70	1050	0.97		
500	0.80	1100	0.84		
550	0.88	1150	0.68		

Curve developed by New Mexico State University

Figure 30: Turf-Park Curve



Polynominal Function for Turf-Park

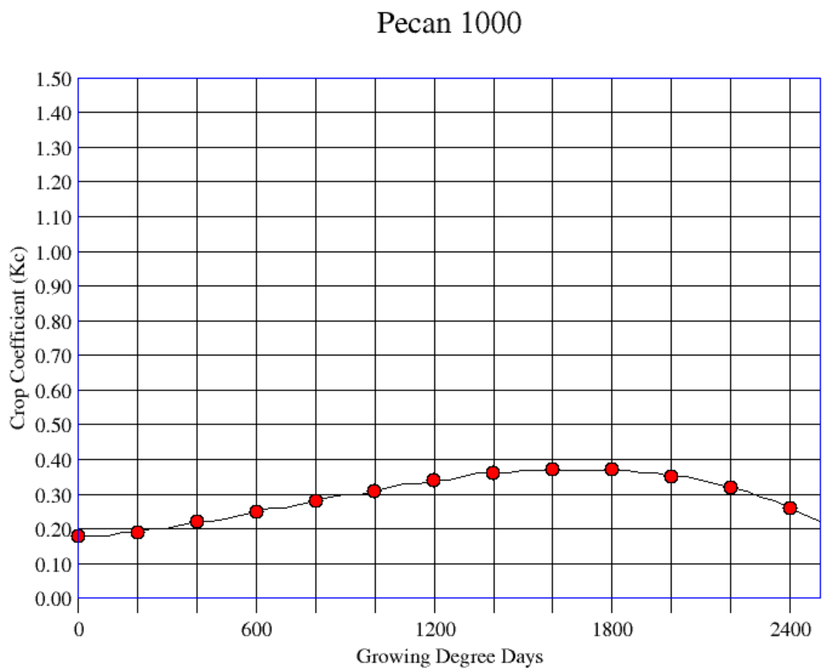
```
Kc  =    0.65E+00 +   0.000E+00(GDD) +   0.000E+00(GDD)**2 +
                      0.000E+00(GDD)**3 +   0.000E+00(GDD)**4 +
                      0.000E+00(GDD)**5
```

Base Temperature (deg. C) =   5.0

GDD	Kc	GDD	Kc	GDD	Kc
0	0.65	600	0.65	1200	0.65
50	0.65	650	0.65	1250	0.65
100	0.65	700	0.65	1300	0.65
150	0.65	750	0.65	1350	0.65
200	0.65	800	0.65	1400	0.65
250	0.65	850	0.65	1450	0.65
300	0.65	900	0.65	1500	0.65
350	0.65	950	0.65	1550	0.65
400	0.65	1000	0.65	1600	0.65
450	0.65	1050	0.65	1650	0.65
500	0.65	1100	0.65	1700	0.65
550	0.65	1150	0.65		

Curve developed by New Mexico State University

Figure 31: Pecan 1000 Curve

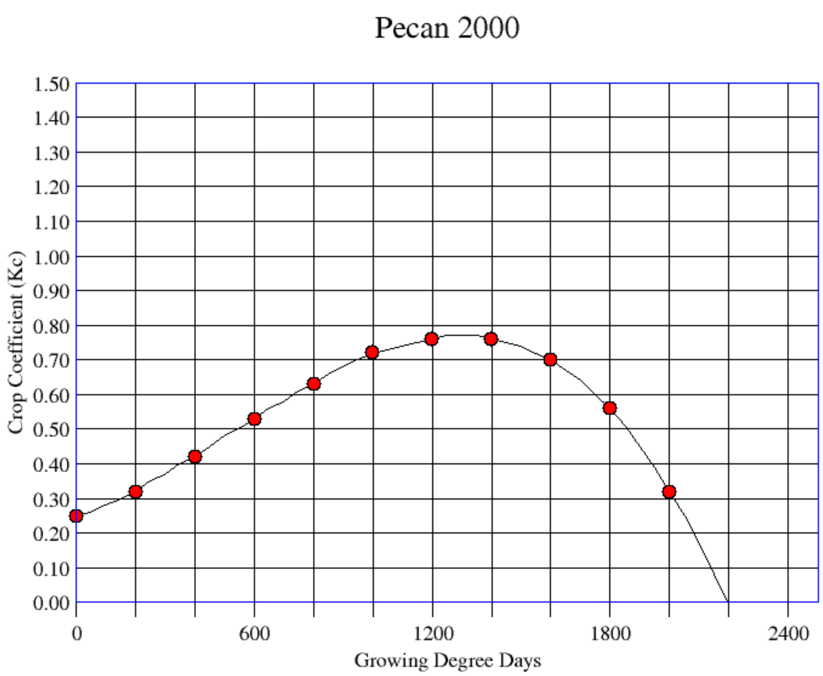



```
                 Polynominal Function for Pecan 1000

Kc  =    0.18E+00 +   0.569E-04(GDD) +   0.140E-06(GDD)**2 +
                     -0.621E-10(GDD)**3 +   0.000E+00(GDD)**4 +
                      0.000E+00(GDD)**5

Min. Cutoff Temperature (deg. C) =  -4.0
Base Temperature (deg. C) =  15.5
```

GDD	Kc	GDD	Kc	GDD	Kc	GDD	Kc	GDD	Kc
0	0.18	600	0.25	1200	0.34	1800	0.37	2400	0.26
50	0.18	650	0.26	1250	0.34	1850	0.37	2450	0.24
100	0.18	700	0.26	1300	0.35	1900	0.36	2500	0.22
150	0.19	750	0.27	1350	0.36	1950	0.36		
200	0.19	800	0.28	1400	0.36	2000	0.35		
250	0.20	850	0.29	1450	0.36	2050	0.35		
300	0.20	900	0.30	1500	0.37	2100	0.34		
350	0.21	950	0.30	1550	0.37	2150	0.33		
400	0.22	1000	0.31	1600	0.37	2200	0.32		
450	0.22	1050	0.32	1650	0.37	2250	0.31		
500	0.23	1100	0.33	1700	0.37	2300	0.29		
550	0.24	1150	0.33	1750	0.37	2350	0.28		

Curve developed by New Mexico State University

Figure 32: Pecan 2000 Curve

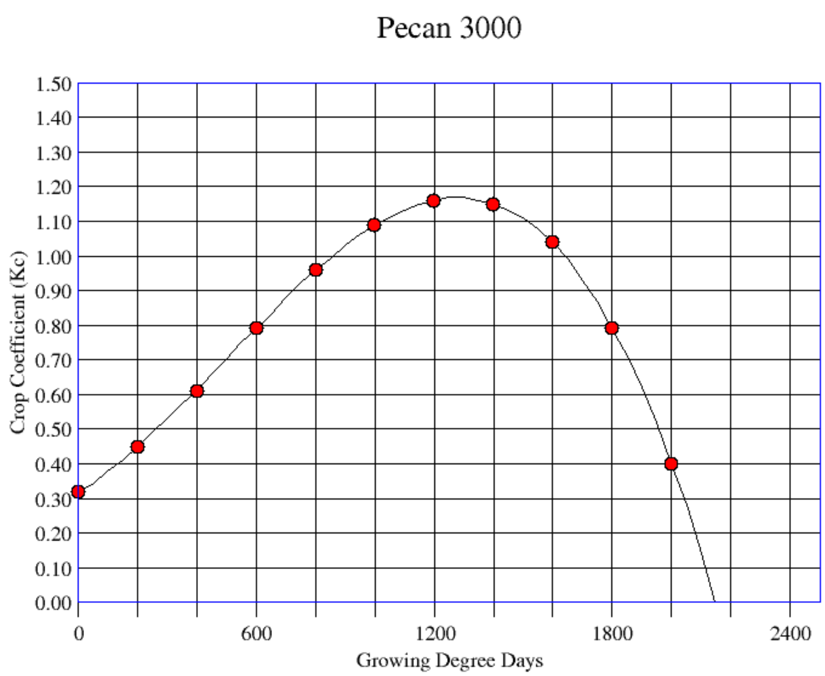



```
                 Polynominal Function for Pecan 2000

Kc  =    0.25E+00 +   0.305E-03(GDD) +   0.461E-06(GDD)**2 +
                    -0.297E-09(GDD)**3 +   0.000E+00(GDD)**4 +
                     0.000E+00(GDD)**5

Min. Cutoff Temperature (deg. C) =  -4.0
Base Temperature (deg. C) =  15.5
```

GDD	Kc	GDD	Kc	GDD	Kc	GDD	Kc
0	0.25	600	0.53	1200	0.76	1800	0.56
50	0.26	650	0.56	1250	0.77	1850	0.51
100	0.28	700	0.58	1300	0.77	1900	0.45
150	0.30	750	0.61	1350	0.77	1950	0.39
200	0.32	800	0.63	1400	0.76	2000	0.32
250	0.35	850	0.66	1450	0.75	2050	0.25
300	0.37	900	0.68	1500	0.74	2100	0.17
350	0.40	950	0.70	1550	0.72	2150	0.08
400	0.42	1000	0.72	1600	0.70		
450	0.45	1050	0.73	1650	0.67		
500	0.48	1100	0.74	1700	0.64		
550	0.50	1150	0.75	1750	0.60		

Curve developed by New Mexico State University

Figure 33: Pecan 3000 Curve

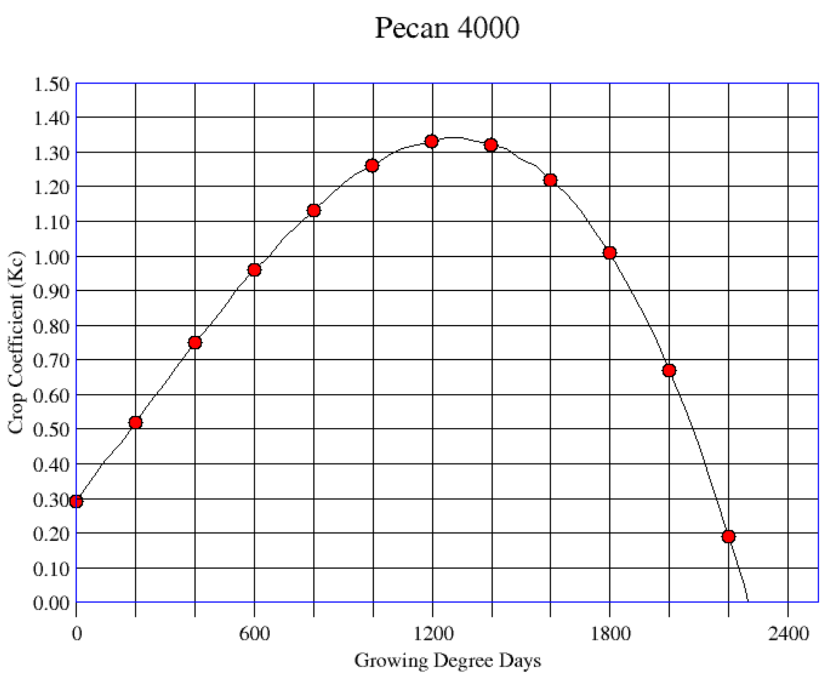



```
                 Polynominal Function for Pecan 3000

Kc  =    0.32E+00 +   0.531E-03(GDD) +   0.724E-06(GDD)**2 +
                    -0.484E-09(GDD)**3 +   0.000E+00(GDD)**4 +
                     0.000E+00(GDD)**5

Min. Cutoff Temperature (deg. C) =  -4.0
Base Temperature (deg. C) =  15.5
```

GDD	Kc	GDD	Kc	GDD	Kc	GDD	Kc
0	0.32	600	0.79	1200	1.16	1800	0.79
50	0.34	650	0.83	1250	1.17	1850	0.71
100	0.38	700	0.88	1300	1.17	1900	0.62
150	0.41	750	0.92	1350	1.16	1950	0.52
200	0.45	800	0.96	1400	1.15	2000	0.40
250	0.49	850	0.99	1450	1.13	2050	0.28
300	0.53	900	1.03	1500	1.11	2100	0.14
350	0.57	950	1.06	1550	1.08		
400	0.61	1000	1.09	1600	1.04		
450	0.66	1050	1.11	1650	0.99		
500	0.70	1100	1.13	1700	0.93		
550	0.75	1150	1.15	1750	0.87		

Curve developed by New Mexico State University

Figure 34: Pecan 4000 Curve

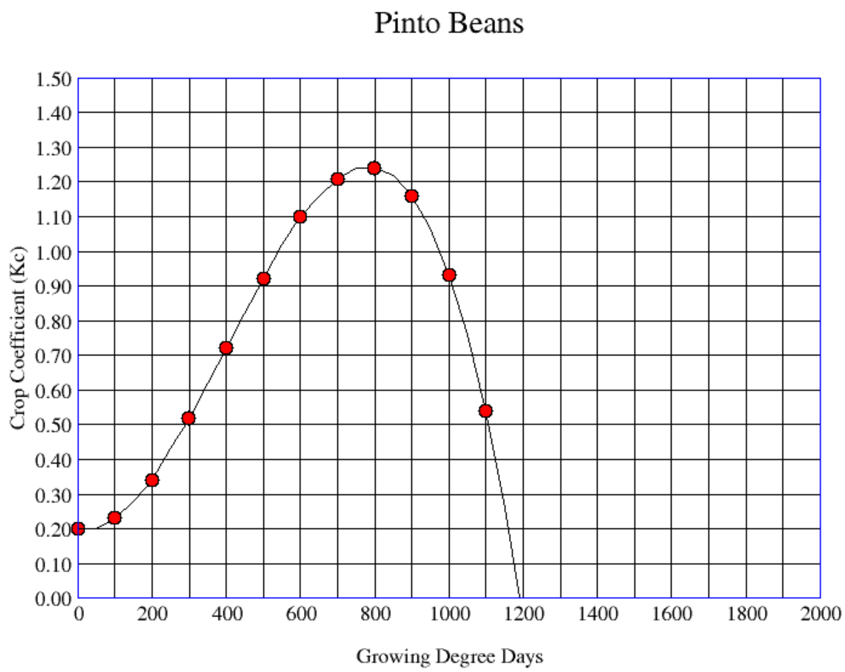



```
                    Polynominal Function for Pecan 4000

Kc  =    0.29E+00 +   0.111E-02(GDD) +   0.185E-06(GDD)**2 +
                     -0.323E-09(GDD)**3 +   0.000E+00(GDD)**4 +
                      0.000E+00(GDD)**5

Min. Cutoff Temperature (deg. C) =  -4.0
Base Temperature (deg. C) =  15.5
```

GDD	Kc	GDD	Kc	GDD	Kc	GDD	Kc
0	0.29	600	0.96	1200	1.33	1800	1.01
50	0.35	650	1.00	1250	1.34	1850	0.93
100	0.41	700	1.05	1300	1.34	1900	0.85
150	0.46	750	1.09	1350	1.33	1950	0.77
200	0.52	800	1.13	1400	1.32	2000	0.67
250	0.58	850	1.17	1450	1.31	2050	0.56
300	0.63	900	1.21	1500	1.28	2100	0.45
350	0.69	950	1.24	1550	1.26	2150	0.32
400	0.75	1000	1.26	1600	1.22	2200	0.19
450	0.80	1050	1.29	1650	1.18	2250	0.05
500	0.85	1100	1.31	1700	1.13		
550	0.91	1150	1.32	1750	1.07		

Curve developed by New Mexico State University

Figure 35: Pinto Beans Curve

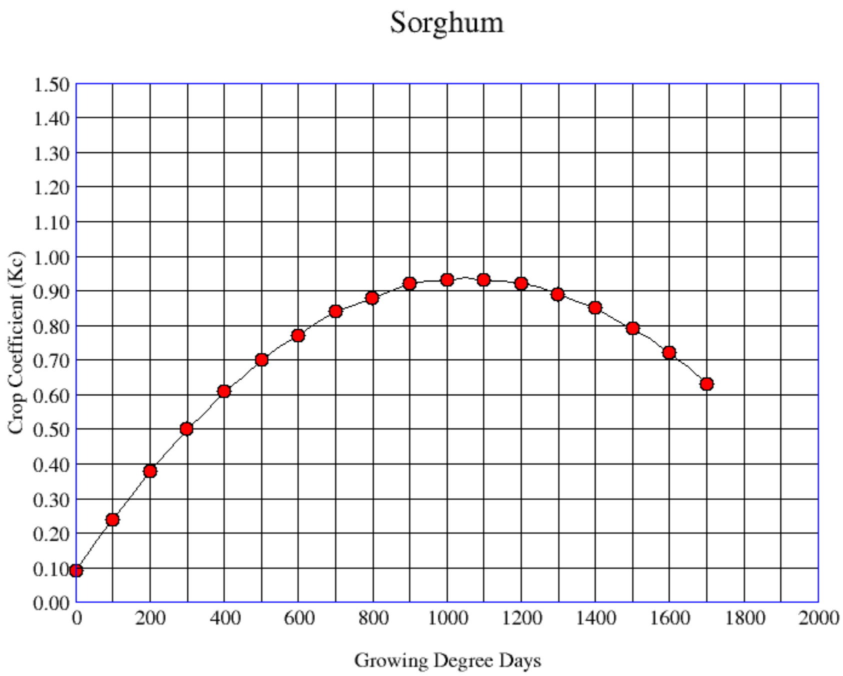



```
                Polynominal Function for Pinto Beans

Kc  =    0.20E+00 +  -0.212E-03(GDD) +   0.572E-05(GDD)**2 +
                    -0.477E-08(GDD)**3 +   0.000E+00(GDD)**4 +
                     0.000E+00(GDD)**5

Max. Cutoff Temperature (deg. C) =  30.0
Min. Cutoff Temperature (deg. C) =  10.0
Base Temperature (deg. C) =  10.0
```

GDD	Kc	GDD	Kc	GDD	Kc
0	0.20	600	1.10		
50	0.20	650	1.16		
100	0.23	700	1.21		
150	0.28	750	1.24		
200	0.34	800	1.24		
250	0.43	850	1.22		
300	0.52	900	1.16		
350	0.62	950	1.07		
400	0.72	1000	0.93		
450	0.82	1050	0.76		
500	0.92	1100	0.54		
550	1.02	1150	0.26		

Curve developed by New Mexico State University

Figure 36: Sorghum Curve

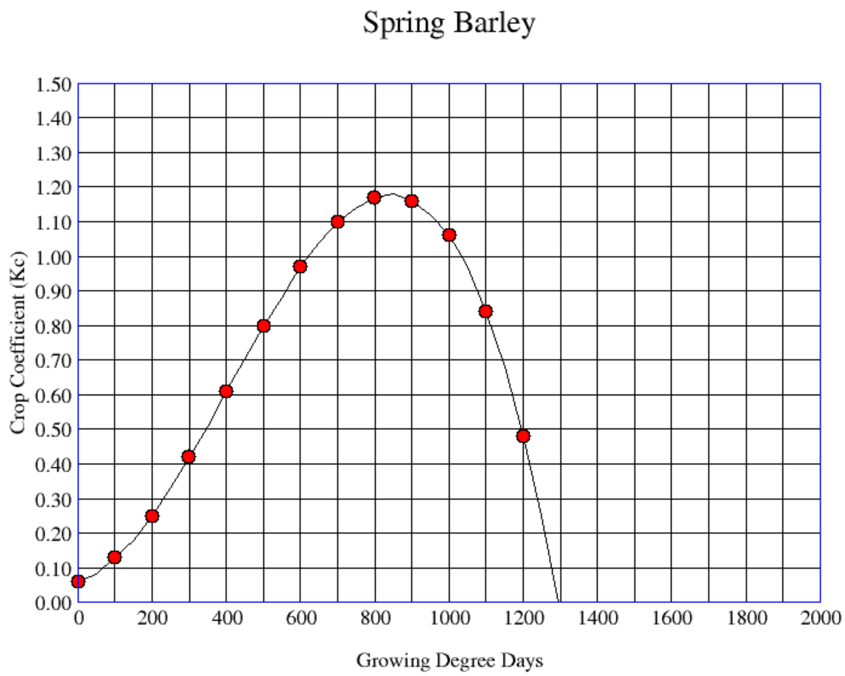



```
                 Polynominal Function for Sorghum

Kc  =    0.89E-01 +   0.159E-02(GDD) +  -0.746E-06(GDD)**2 +
                    -0.836E-12(GDD)**3 +   0.000E+00(GDD)**4 +
                     0.000E+00(GDD)**5

Base Temperature (deg. C) =   7.0
```

GDD	Kc	GDD	Kc	GDD	Kc
0	0.09	600	0.77	1200	0.92
50	0.17	650	0.81	1250	0.91
100	0.24	700	0.84	1300	0.89
150	0.31	750	0.86	1350	0.87
200	0.38	800	0.88	1400	0.85
250	0.44	850	0.90	1450	0.82
300	0.50	900	0.92	1500	0.79
350	0.55	950	0.93	1550	0.76
400	0.61	1000	0.93	1600	0.72
450	0.65	1050	0.94	1650	0.68
500	0.70	1100	0.93	1700	0.63
550	0.74	1150	0.93		

Curve developed by New Mexico State University

Figure 37: Spring Barley Curve

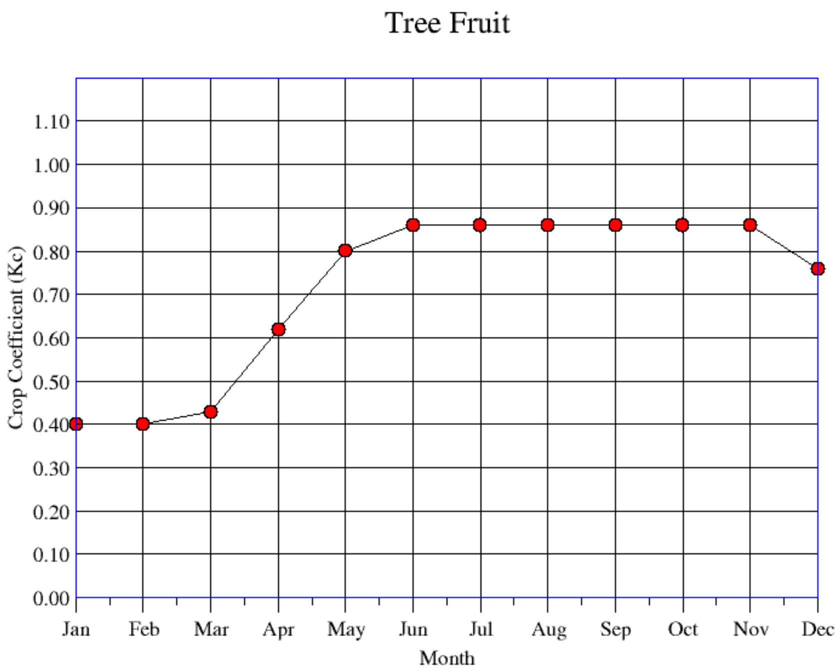



```
                Polynominal Function for Spring Barley

Kc  =    0.57E-01 +   0.323E-03(GDD) +   0.394E-05(GDD)**2 +
                     -0.326E-08(GDD)**3 +   0.000E+00(GDD)**4 +
                      0.000E+00(GDD)**5

Max. Cutoff Temperature (deg. C) =  30.0
Min. Cutoff Temperature (deg. C) =   5.0
Base Temperature (deg. C) =   5.0
```

GDD	Kc	GDD	Kc	GDD	Kc
----	----	----	----	----	----
0	0.06	600	0.97	1200	0.48
50	0.08	650	1.04	1250	0.25
100	0.13	700	1.10		
150	0.18	750	1.14		
200	0.25	800	1.17		
250	0.33	850	1.18		
300	0.42	900	1.16		
350	0.51	950	1.12		
400	0.61	1000	1.06		
450	0.70	1050	0.97		
500	0.80	1100	0.84		
550	0.88	1150	0.68		

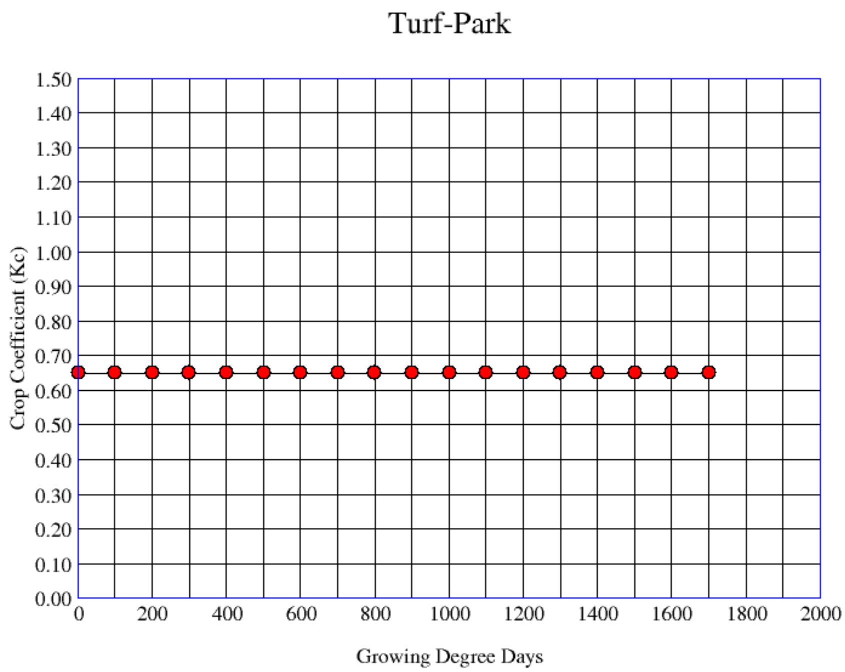
Curve developed by New Mexico State University

Figure 38: Tree Fruit Curve




```
 Monthly Coefficients for Tree Fruit

 Month     Crop Coefficient (Kc)
---------  ---------------------
January          0.40
February         0.40
March            0.43
April            0.62
May              0.80
June             0.86
July             0.86
August           0.86
September        0.86
October          0.86
November         0.86
December         0.76

Data from Jensen,M.E., (1998)
```

Figure 39: Turf-Park Curve



Polynominal Function for Turf-Park

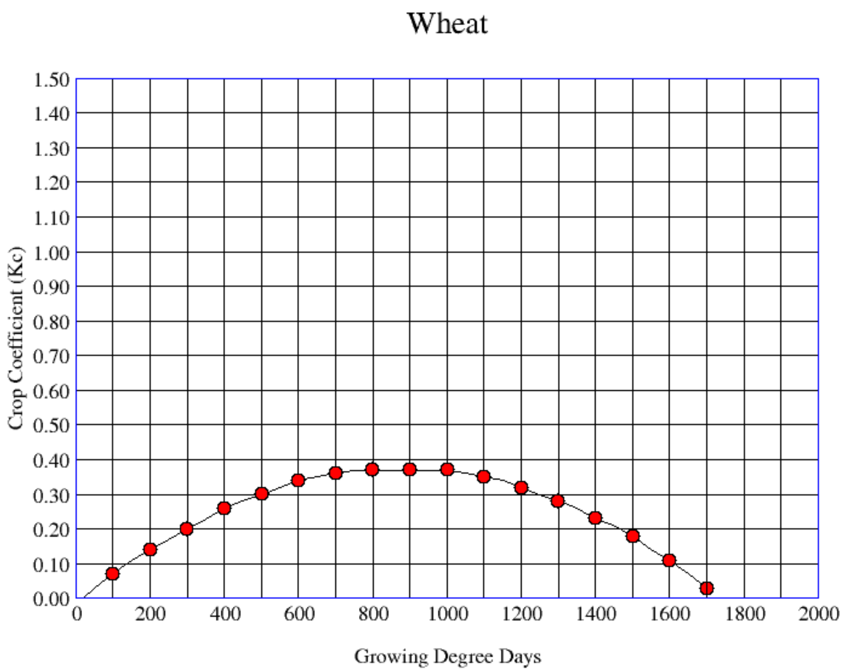
```
Kc  =    0.65E+00 +   0.000E+00(GDD) +   0.000E+00(GDD)**2 +
                      0.000E+00(GDD)**3 +   0.000E+00(GDD)**4 +
                      0.000E+00(GDD)**5
```

Base Temperature (deg. C) =   5.0

GDD	Kc	GDD	Kc	GDD	Kc
0	0.65	600	0.65	1200	0.65
50	0.65	650	0.65	1250	0.65
100	0.65	700	0.65	1300	0.65
150	0.65	750	0.65	1350	0.65
200	0.65	800	0.65	1400	0.65
250	0.65	850	0.65	1450	0.65
300	0.65	900	0.65	1500	0.65
350	0.65	950	0.65	1550	0.65
400	0.65	1000	0.65	1600	0.65
450	0.65	1050	0.65	1650	0.65
500	0.65	1100	0.65	1700	0.65
550	0.65	1150	0.65		

Curve developed by New Mexico State University

Figure 40: Wheat Curve

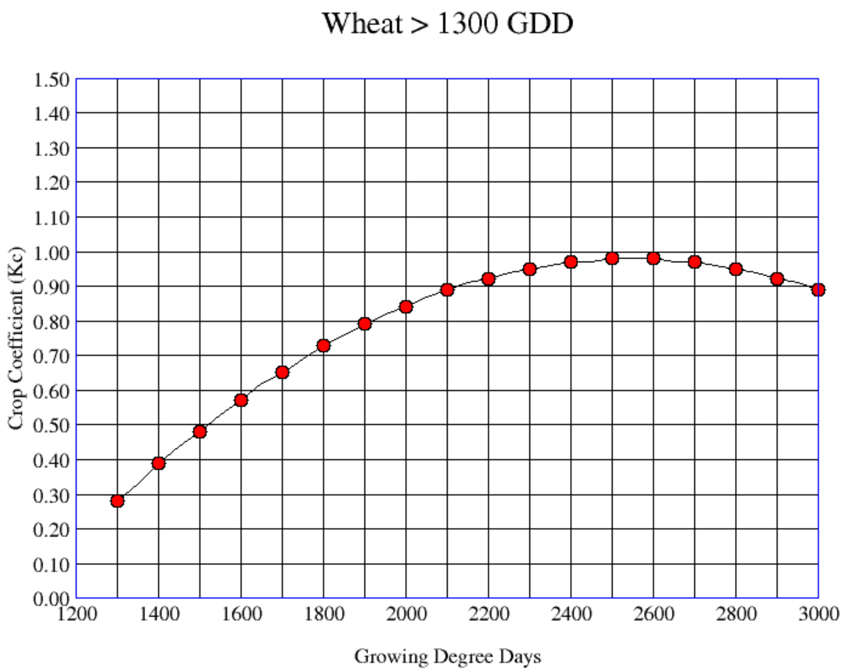



```
                 Polynominal Function for Wheat

Kc  =   -0.17E-01 +   0.894E-03(GDD) +  -0.510E-06(GDD)**2 +
                   0.000E+00(GDD)**3 +   0.000E+00(GDD)**4 +
                   0.000E+00(GDD)**5

Max. Cutoff Temperature (deg. C) =  27.0
Min. Cutoff Temperature (deg. C) =   4.0
Base Temperature (deg. C) =   4.0
```

GDD	Kc	GDD	Kc	GDD	Kc
50	0.03	650	0.35	1250	0.30
100	0.07	700	0.36	1300	0.28
150	0.11	750	0.37	1350	0.26
200	0.14	800	0.37	1400	0.23
250	0.17	850	0.37	1450	0.21
300	0.20	900	0.37	1500	0.18
350	0.23	950	0.37	1550	0.14
400	0.26	1000	0.37	1600	0.11
450	0.28	1050	0.36	1650	0.07
500	0.30	1100	0.35	1700	0.03
550	0.32	1150	0.34		
600	0.34	1200	0.32		

Curve developed by New Mexico State University

Figure 41: Wheat>1300 GDD Curve

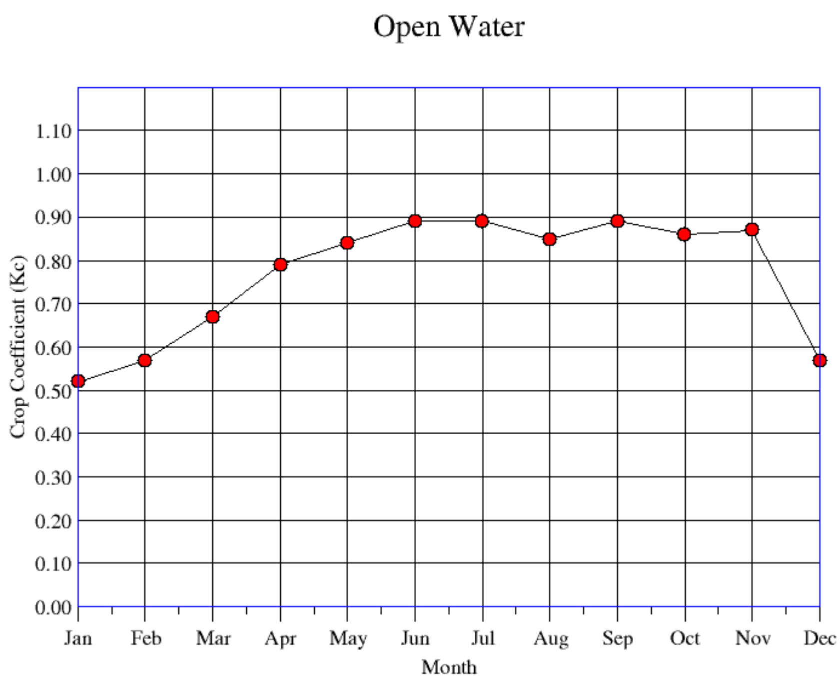



```
                Polynominal Function for Wheat > 1300 GDD

Kc  =   -0.19E+01 +   0.228E-02(GDD) +  -0.447E-06(GDD)**2 +
                    0.000E+00(GDD)**3 +   0.000E+00(GDD)**4 +
                    0.000E+00(GDD)**5

Max. Cutoff Temperature (deg. C) =  27.0
Min. Cutoff Temperature (deg. C) =   4.0
Base Temperature (deg. C) =   4.0
```

GDD	Kc	GDD	Kc	GDD	Kc
1300	0.28	1900	0.79	2500	0.98
1350	0.33	1950	0.82	2550	0.98
1400	0.39	2000	0.84	2600	0.98
1450	0.44	2050	0.87	2650	0.97
1500	0.48	2100	0.89	2700	0.97
1550	0.53	2150	0.91	2750	0.96
1600	0.57	2200	0.92	2800	0.95
1650	0.62	2250	0.94	2850	0.94
1700	0.65	2300	0.95	2900	0.92
1750	0.69	2350	0.96	2950	0.91
1800	0.73	2400	0.97	3000	0.89
1850	0.76	2450	0.97		

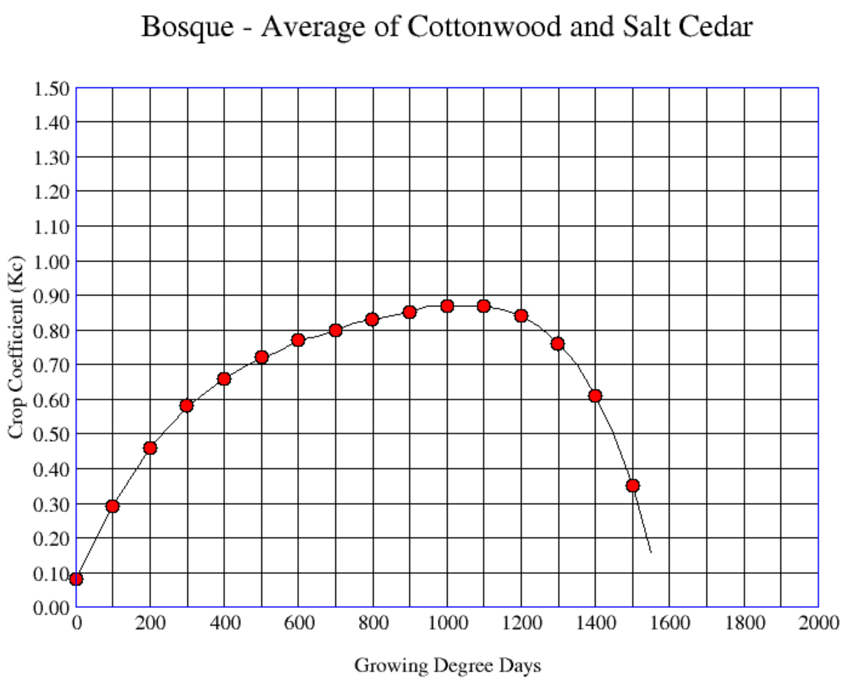
Curve developed by New Mexico State University

Figure 42: Open Water Curve




```
 Monthly Coefficients for Open Water

 Month     Crop Coefficient (Kc)
---------  ---------------------
January           0.52
February          0.57
March             0.67
April             0.79
May               0.84
June              0.89
July              0.89
August            0.85
September         0.89
October           0.86
November          0.87
December          0.57

Data from Jensen,M.E., (1998)
```

Figure 43: Bosque Average Curve



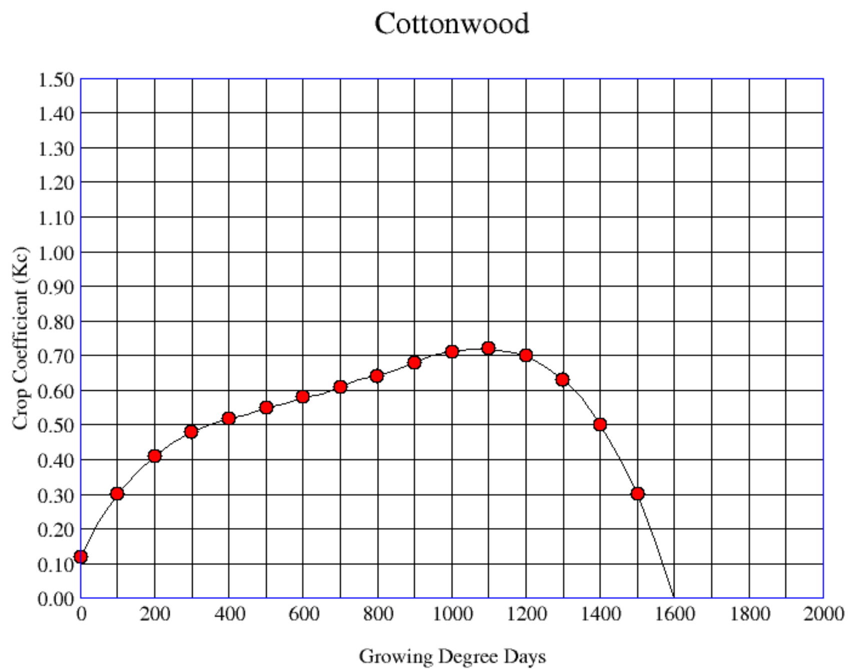
Polynominal Function for Bosque

The Bosque uses an average of the Kc calculated from the Cottonwood and Salt Cedar polynominal functions. Refer to them. In May, June, and July, the Kc is set to 1.00

GDD	Kc	GDD	Kc	GDD	Kc
0	0.08	600	0.77	1200	0.84
50	0.19	650	0.78	1250	0.81
100	0.29	700	0.80	1300	0.76
150	0.38	750	0.82	1350	0.70
200	0.46	800	0.83	1400	0.61
250	0.52	850	0.84	1450	0.50
300	0.58	900	0.85	1500	0.35
350	0.62	950	0.87	1550	0.16
400	0.66	1000	0.87		
450	0.66	1050	0.87		
500	0.72	1100	0.87		
550	0.74	1150	0.86		

Curve developed by New Mexico State University

Figure 44: Cottonwood Curve

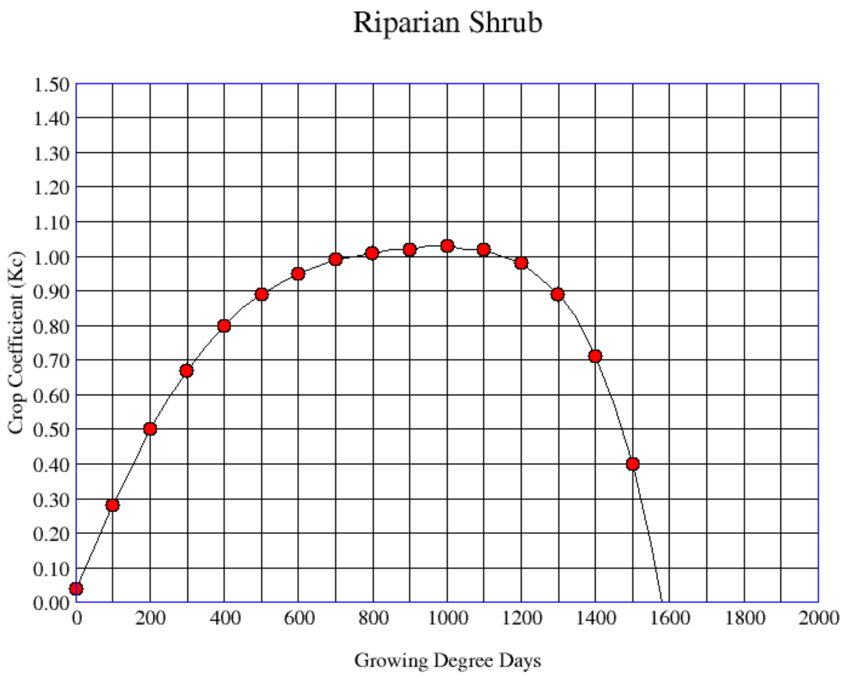



```
                Polynominal Function for Cottonwood

Kc   =     0.12E+00 +    0.225E-02(GDD) +  -0.506E-05(GDD)**2 +
                       0.585E-08(GDD)**3 +  -0.279E-11(GDD)**4 +
                       0.338E-15(GDD)**5

Min. Cutoff Temperature (deg. C) =  15.5
Base Temperature (deg. C) =  15.5
```

GDD	Kc	GDD	Kc	GDD	Kc
0	0.12	600	0.58	1200	0.70
50	0.22	650	0.59	1250	0.67
100	0.30	700	0.61	1300	0.63
150	0.36	750	0.63	1350	0.58
200	0.41	800	0.64	1400	0.50
250	0.45	850	0.66	1450	0.41
300	0.48	900	0.68	1500	0.30
350	0.50	950	0.70	1550	0.16
400	0.52	1000	0.71		
450	0.53	1050	0.72		
500	0.55	1100	0.72		
550	0.56	1150	0.71		

Curve developed by New Mexico State University

Figure 45: Riparian Shrub Curve

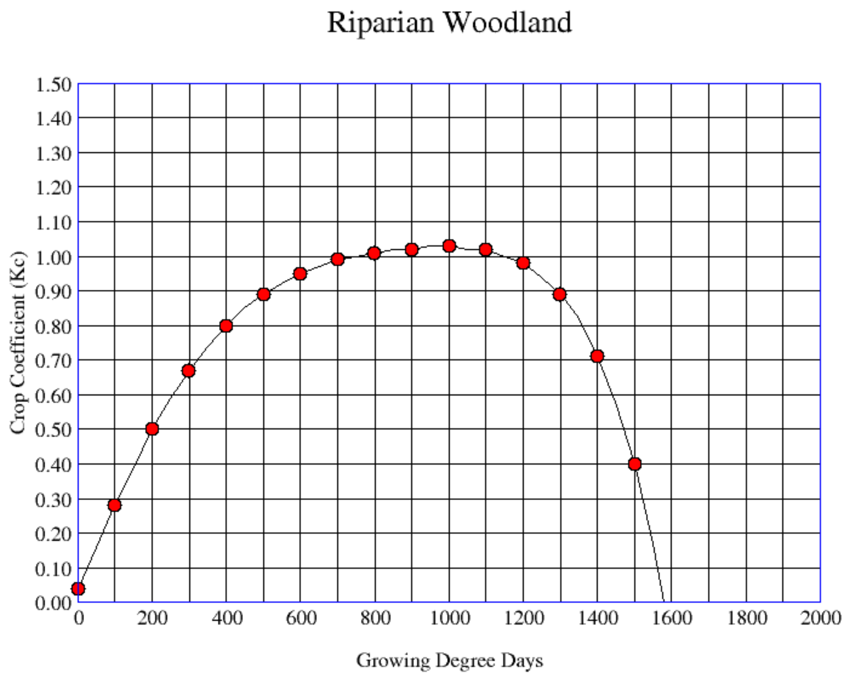



```
                    Polynominal Function for Riparian Shrub

Kc  =    0.40E-01 +   0.253E-02(GDD) +  -0.653E-06(GDD)**2 +
                  -0.395E-08(GDD)**3 +   0.469E-11(GDD)**4 +
                  -0.163E-14(GDD)**5

Min. Cutoff Temperature (deg. C) =  15.5
Base Temperature (deg. C) =  15.5
```

GDD	Kc	GDD	Kc	GDD	Kc
0	0.04	600	0.95	1200	0.98
50	0.16	650	0.97	1250	0.94
100	0.28	700	0.99	1300	0.89
150	0.39	750	1.00	1350	0.82
200	0.50	800	1.01	1400	0.71
250	0.59	850	1.02	1450	0.58
300	0.67	900	1.02	1500	0.40
350	0.74	950	1.03	1550	0.17
400	0.80	1000	1.03		
450	0.85	1050	1.02		
500	0.89	1100	1.02		
550	0.92	1150	1.00		

Curve developed by New Mexico State University

Figure 46: Riparian Woodland Curve



Polynominal Function for Riparian Woodland

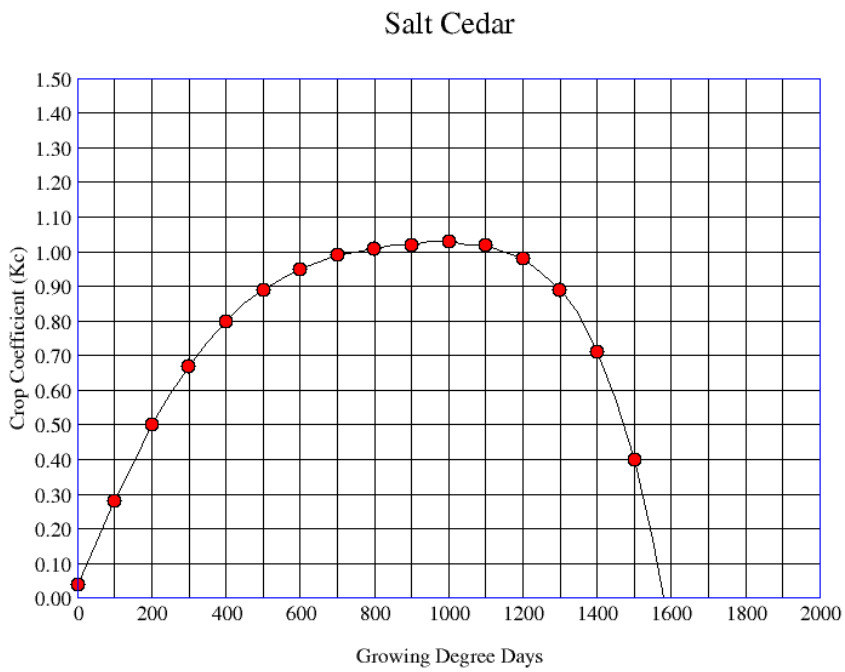
```
Kc  =    0.40E-01 +   0.253E-02(GDD) +  -0.653E-06(GDD)**2 +
                 -0.395E-08(GDD)**3 +   0.469E-11(GDD)**4 +
                 -0.163E-14(GDD)**5
```

Min. Cutoff Temperature (deg. C) = 15.5
Base Temperature (deg. C) = 15.5

GDD	Kc	GDD	Kc	GDD	Kc
0	0.04	600	0.95	1200	0.98
50	0.16	650	0.97	1250	0.94
100	0.28	700	0.99	1300	0.89
150	0.39	750	1.00	1350	0.82
200	0.50	800	1.01	1400	0.71
250	0.59	850	1.02	1450	0.58
300	0.67	900	1.02	1500	0.40
350	0.74	950	1.03	1550	0.17
400	0.80	1000	1.03		
450	0.85	1050	1.02		
500	0.89	1100	1.02		
550	0.92	1150	1.00		

Curve developed by New Mexico State University

Figure 47: Salt Cedar Curve

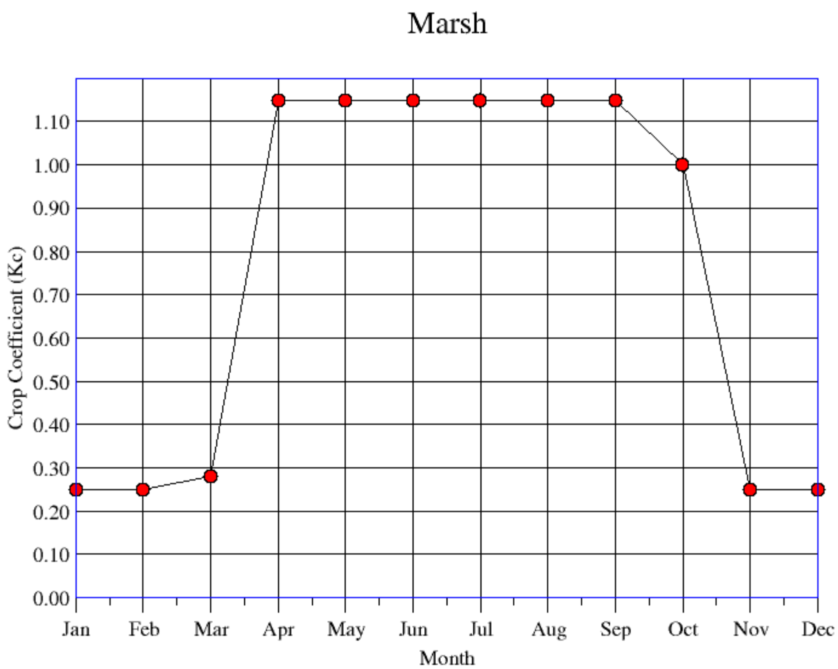



```
                Polynominal Function for Salt Cedar

Kc  =    0.40E-01 +   0.253E-02(GDD) +  -0.653E-06(GDD)**2 +
                  -0.395E-08(GDD)**3 +   0.469E-11(GDD)**4 +
                  -0.163E-14(GDD)**5

Min. Cutoff Temperature (deg. C) =  15.5
Base Temperature (deg. C) =  15.5
```

GDD	Kc	GDD	Kc	GDD	Kc
0	0.04	600	0.95	1200	0.98
50	0.16	650	0.97	1250	0.94
100	0.28	700	0.99	1300	0.89
150	0.39	750	1.00	1350	0.82
200	0.50	800	1.01	1400	0.71
250	0.59	850	1.02	1450	0.58
300	0.67	900	1.02	1500	0.40
350	0.74	950	1.03	1550	0.17
400	0.80	1000	1.03		
450	0.85	1050	1.02		
500	0.89	1100	1.02		
550	0.92	1150	1.00		

Curve developed by New Mexico State University

Figure 48: Marsh Curve




```
 Monthly Coefficients for Marsh

 Month     Crop Coefficient (Kc)
--------- ---------------------
January          0.25
February         0.25
March            0.28
April            1.15
May              1.15
June             1.15
July             1.15
August           1.15
September        1.15
October          1.00
November         0.25
December         0.25

Data from Jensen,M.E., (1998)
```

```
                                                                                     Printed by AlBrower
Jun 24, 03 15:57                              REA3.ettool                                       Page 1/1
REA3 URGWOM Reach 3 (San Felipe to Cent. Ave. gage)          LUTA  1992/93
 ANGN Angostura, NM - MRGCD                                101 2003
  108x313                    12 |  1     2.5 |  3     1.1 |  8     3.8 |  9    24.5 |  10    14.9 |  20   625.8 |  21   317.8 |  23    49.4 |  26     7.1 |  28     1.6 |  33    14.2 |  34    32.9 |
    101   0.00    53.4    0.26 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.25      |   0.00      |   0.01      |   0.00      |   0.00      |
    102   0.00    53.4    0.17 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.16      |   0.00      |   0.00      |   0.00      |   0.00      |
    103   0.00    53.4    0.22 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.21      |   0.00      |   0.01      |   0.00      |   0.00      |
    104   0.00    53.4    0.26 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.25      |   0.00      |   0.01      |   0.00      |   0.00      |
    105   0.00    53.4    0.26 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.25      |   0.00      |   0.01      |   0.00      |   0.00      |
    106   0.00    53.4    0.30 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.29      |   0.00      |   0.01      |   0.00      |   0.00      |
    107   0.00    53.4    0.22 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.21      |   0.00      |   0.01      |   0.00      |   0.00      |
    108   0.00    53.4    0.22 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.21      |   0.00      |   0.01      |   0.00      |   0.00      |
    109   0.00    53.4    0.17 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.16      |   0.00      |   0.00      |   0.00      |   0.00      |
    110   0.00    53.4    0.22 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.21      |   0.00      |   0.01      |   0.00      |   0.00      |
    111   0.00    53.4    0.13 |   0.00      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.12      |   0.00      |   0.00      |   0.00      |   0.00      |
    112   0.00    53.4    0.22 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.21      |   0.00      |   0.01      |   0.00      |   0.00      |
    113   0.00    53.4    0.22 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.21      |   0.00      |   0.01      |   0.00      |   0.00      |
    114   0.00    53.4    0.22 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.21      |   0.00      |   0.01      |   0.00      |   0.00      |
    115   0.00    53.4    0.30 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.29      |   0.00      |   0.01      |   0.00      |   0.00      |
    116   0.00    53.4    0.30 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.29      |   0.00      |   0.01      |   0.00      |   0.00      |
    117   0.00    53.4    0.30 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.29      |   0.00      |   0.01      |   0.00      |   0.00      |
    118   0.00    53.4    0.30 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.29      |   0.00      |   0.01      |   0.00      |   0.00      |
    119   0.00    53.4    0.30 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.29      |   0.00      |   0.01      |   0.00      |   0.00      |
    120   0.00    53.4    0.30 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.29      |   0.00      |   0.01      |   0.00      |   0.00      |
    121   0.00    53.4    0.30 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.29      |   0.00      |   0.01      |   0.00      |   0.00      |
    122   0.00    53.4    0.30 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.29      |   0.00      |   0.01      |   0.00      |   0.00      |
    123   0.00    53.4    0.30 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.29      |   0.00      |   0.01      |   0.00      |   0.00      |
    124   0.00    53.4    0.30 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.29      |   0.00      |   0.01      |   0.00      |   0.00      |
    125   0.00    53.4    0.26 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.25      |   0.00      |   0.01      |   0.00      |   0.00      |
    126   0.00    53.4    0.30 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.29      |   0.00      |   0.01      |   0.00      |   0.00      |
    127   0.00    53.4    0.35 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.33      |   0.00      |   0.01      |   0.00      |   0.00      |
    128   0.00    53.4    0.39 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.37      |   0.00      |   0.01      |   0.00      |   0.00      |
    129   0.00    53.4    0.30 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.29      |   0.00      |   0.01      |   0.00      |   0.00      |
    130   0.00    53.4    0.39 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.37      |   0.00      |   0.01      |   0.00      |   0.00      |
    131   0.00    53.4    0.39 |   0.01      |   0.00     |   0.00     |   0.00     |   0.00      |   0.00      |   0.00      |   0.37      |   0.00      |   0.01      |   0.00      |   0.00      |

Tuesday June 24, 2003                         REA3.ettool                                            1/1
```

Figure 49: ET Toolbox File Example

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```
Description of contents of the ET TOOLBOX file - Sample file name = REA1.e
ttool
--------------------------------------------------------------------------
-----

   The fortran format is included for clarity and can be used by a
   fortran program to read the file.

1. First record:    format = a4,1x,a48,10x,a4,2x,a10
     Reach short name
     Reach long name
     Vegetation classification source
     Vegetation classification year

2. Second record:   format = 1x,a4,1x,a48,5x,i4,1x,i4
     Weather station short name
     Weather station long name
     Start day (month-day - generally Jan 1.)  example: 101 = January 1
     Start year

3. Third record:    format =  2x,i3,1hx,i3,18x,i3,2h |,<inum>(1x,i3,f8.1,2
h |)
     Cell number (x value)
     Cell number (y value)
     Number of land use classifications in this cell (inum)
      The following are repeated for the number of land use classification
s:
        Land use classification
        Acres

4. Fourth record:   format = 3x,i4,f7.2,f8.1,f8.2,2h |,<inum>(f8.2,4x,2h |
)
     Month-day
     Nexrad estimated rainfall for this day in this cell - inches
     Active acres - For water use classifications (those that are active b
ased
                    on plant and terminate dates, riparian, and open water
)
     Total consumptive use for this day - acre-feet
     Consumptive use for each land use classification for this day - acre-
feet

           These fourth records are repeated for each day

5. 7777 record:     format = 3x,4h7777,f7.2,8x,f8.2,2h |,<inum>(f8.2,4x,2h
 |)
     7777
     Total nexrad estimated rainfall to-date for this cell - inches
     Total consumptive use to-date for this cell - acre-feet
     Total consumptive use to-date for each land use classification for
       this cell - acre-feet

6. 8888 record:     format = 3x,4h8888,f7.2,8x,f8.2,2h |
     8888
     Total nexrad estimated rainfall to-date for this weather station - in
ches
     Total consumptive use to-date for this weather station - acre-feet

7. 9999 record:     format = 3x,4h9999,f7.2,8x,f8.2,2h |
     9999
     Total nexrad estimated rainfall to-date for this reach - inches
     Total consumptive use to-date for this reach - acre-feet

LUTA 1992/93 Land Use Classes
```

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```
No.     Class description
 1      Alfalfa
 2      Pasture grasses
 3      Sorghum/Sudex
 4      Wheat
 5      Corn
 6      Chile peppers
 7      Grapes
 8      Fallow agriculture
 9      Idle agriculture
10      Residential
11      Residential-dense
12      Urban irrigated
13      Parks/golf courses
14      Urban vacant
15      Commercial/industrial
16      Riparian woodland
17      Salt Cedar
18      Riparian shrub
19      Marsh
20      Desert scrub
21      Pinon/Juniper
22      Arroyo
23      Open water
24      Miscellaneous grass
25      Quarry/borrow pit
26      Agricultural complex
27      Melons
28      Tree fruit
29      Nursery stock
30      Oats
31      not in the 4 LUTA 1992/93 counties
32      Miscellaneous fruit
33      Miscellaneous vegetables
34      Bosque
35      Cochiti Dam
36      Jemez river channel

40      Cottonwood
```

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Figure 50: ET Toolbox File Description

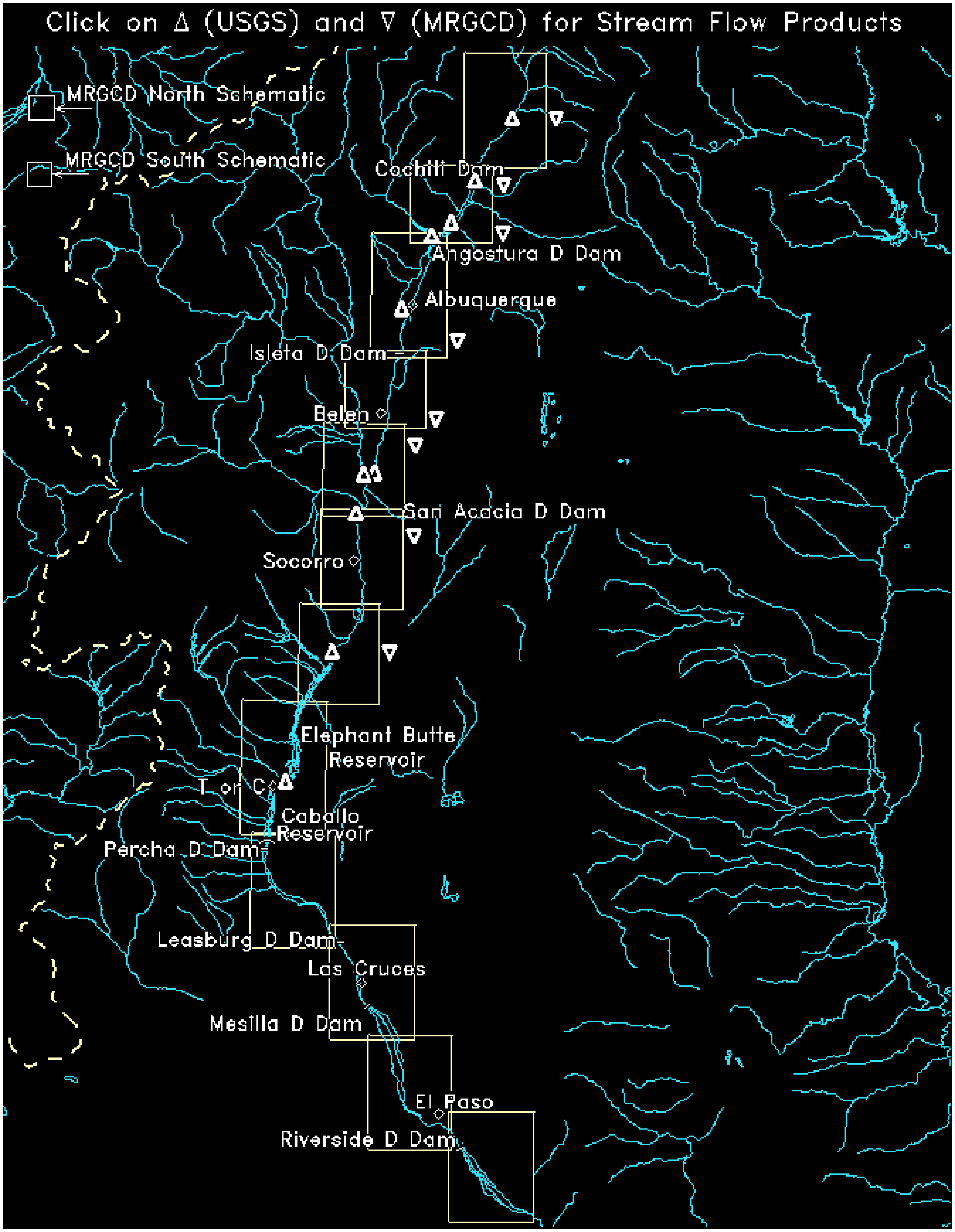

Figure 51: Stream Flow Products

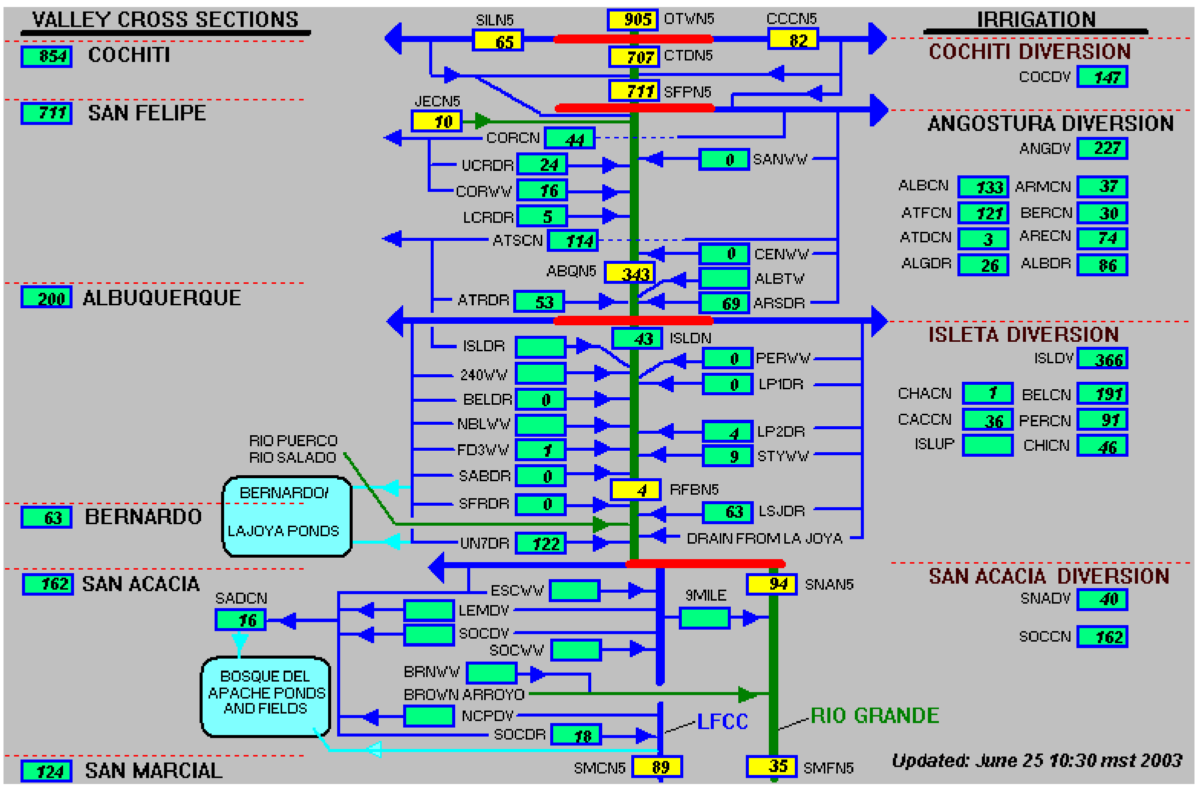

Figure 52: MRGCD North Schematic

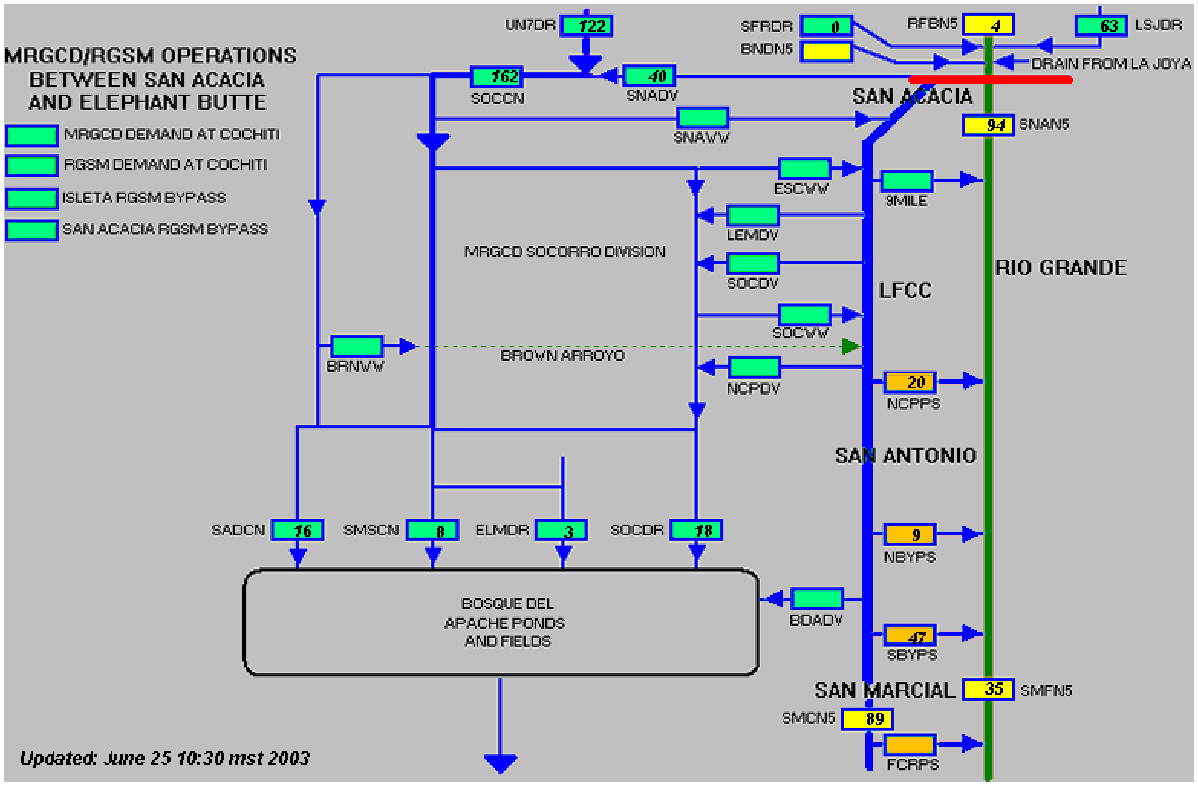

Figure 53: MRGCD South Schematic

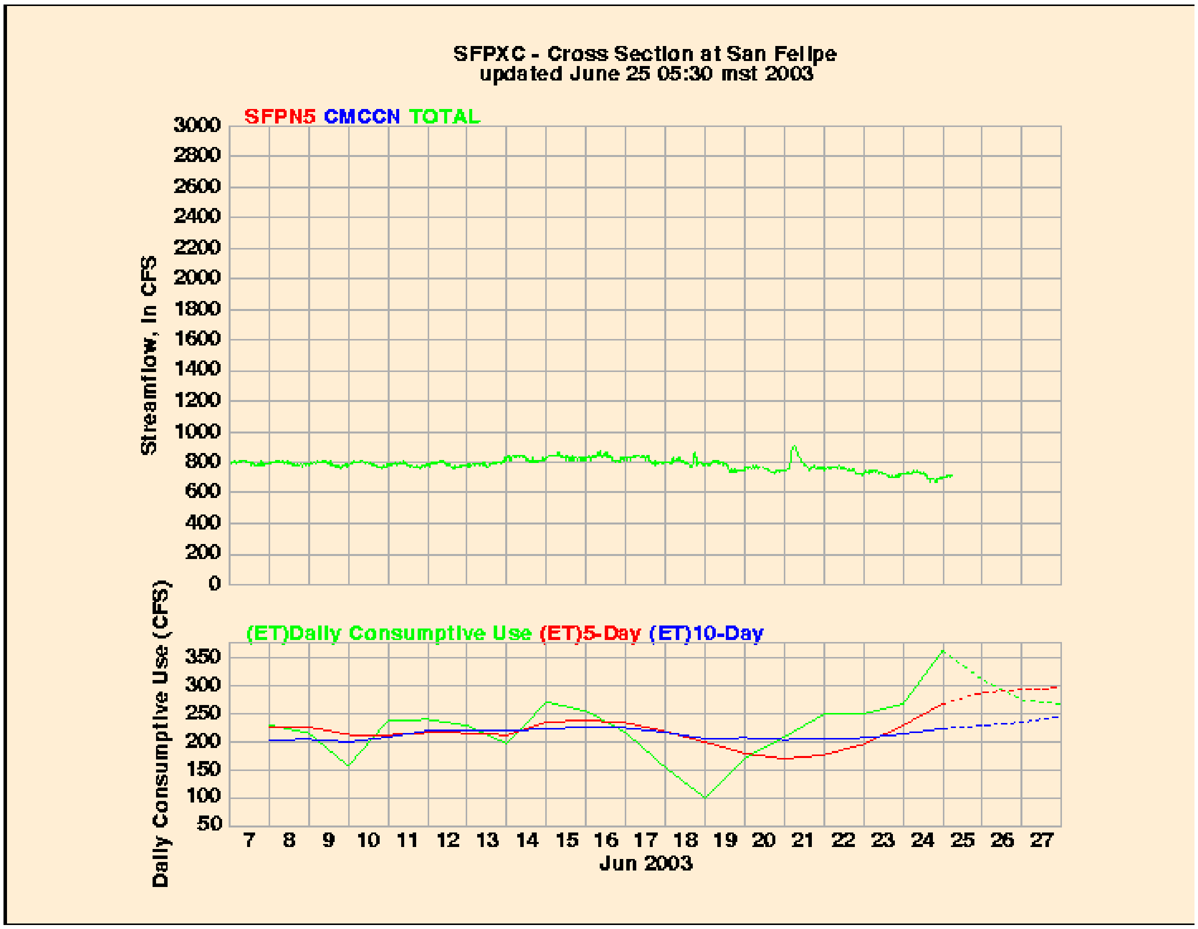

Figure 54: Valley Cross Section

Gage Station Products in Northern New Mexico

OPTIONS (Under Development Prototypes):

LOBC2 – Rio Grande near Lobatas, CO: Plots and Table

RLPN5 – Rio Chama near La Puente: Plots and Table

ELVN5 – El Vado Dam Storage & Elevation: Plots and Table

RCEN5 – Rio Grande below El Vado: Plots and Table

RCAN5 – Rio Chama above Abiquiu Dam: Plots and Table

ABIN5 – Abiquiu Reservoir Storage & Elevation: Plots and Table

AICN5 – Rio Chama below Abiquiu Dam: Plots and Table

RCOPS – Rio Chama Operations: Plots and Table

EMBN5 – Rio Grande at Embudo: Plots and Table

OTWN5 – Rio Grande below Otowi Bridge, near San Idlefonso: Plots and Table

Figure 55: Stream Products Menu